UNIV. OF
TORONTO
LIBRARY

Michigan Engineers' Annual

1896

THE ROOT IMPROVED WATER TUBE BOILER

FURNISHES DRY STEAM.

ABSOLUTE SAFETY

WITH HIGHEST POSSIBLE ECONOMY.

ABENDROTH & ROOT MFG. CO.

SEND FOR CATALOGUE.

28 CLIFF ST., N. Y.

LIDGERWOOD HOISTING ENGINES,

FOR

Engineers, Contractors, Builders, Pile Driving, Etc.

OVER 12,000 IN USE.

300 Styles and Sizes.

ADDRESS,

LIDGERWOOD MFG. CO.,

96 LIBERTY ST., N. Y.

Western Wheeled Scraper Co.

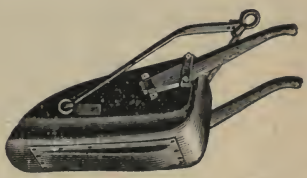
AURORA, ILLINOIS . . .

LARGEST MANUFACTURERS
OF EARTH MOVING MACHINERY
IN THE WORLD.

Our Western Reversible Road Machine . . . needs no lengthy description. It is well known to all practical road men throughout the Union. We have made some additional improvements on it this year, and it is now better than ever.

The . . . Western Wheeled Scraper is the original and practically the only one used by contractors. It has been improved within the last year and it may now be said to be perfect.

The Western Double Bottom All Steel Drag Scraper.



WESTERN RAILROAD AND TOWNSHIP PLOWS,
WESTERN ROCK CRUSHERS,
ELEVATING GRADERS AND DITCHERS,
WESTERN DUMP WAGONS,
WESTERN DUMP CARTS,
WHEEL-BARROWS,
STREET SWEEPERS.

Western Wheeled Scraper Co., Aurora, Illinois.

A

MILWAUKEE CEMENT . . . .

BEST NATURAL CEMENT IN THE WORLD.

Capacity, 4,000 Barrels per Day.

Annual Sales, 400,000 Barrels.

CORRESPONDENCE SOLICITED.

FOR UNIFORMITY OF GRIND AND ULTIMATE STRENGTH IT STANDS UNRIVALLED.

MILWAUKEE CEMENT CO.,

ROOM 7, PLANKINTON BANK BUILDING,

MILWAUKEE, WISCONSIN.

Send for Handbook on Hydraulic Cement, free.
Prompt Shipment Guaranteed.

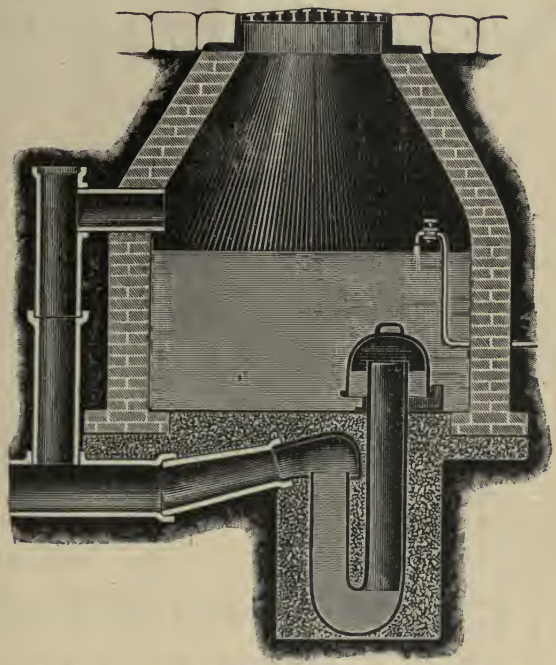
PACIFIC FLUSH TANK CO.

84 LA SALLE ST. CHICAGO.

—— MANUFACTURERS OF ——

THE MILLER AUTOMATIC . . . SIPHON

FOR INTERMITTENT FLUSH TANKS.



USED FOR FLUSHING SEWERS AND FOR SUBSOIL IRRIGATION.

NO MOVING PARTS! NO JOINTS! NO LITTLE TRAPS!

RECEIVED HIGHEST AWARD IN ITS CLASS, WORLD'S COLUMBIAN EXPOSITION, 1893, FOR

EFFECTIVENESS, RELIABILITY,

SIMPLICITY OF CONSTRUCTION.

PORT HURON, MICH., February 20, 1896.

PACIFIC FLUSH TANK CO., Chicago, Ills.

Gentlemen: We placed six of your Miller Automatic Siphons in our Ninth and Tenth Ward sewer systems, built last Fall, and *they are giving excellent satisfaction.* These siphons consist of but two pieces of cast iron, with no movable parts, and I can see no possible chance for them to ever get out of order.

(Signed.) F. F. ROGERS,
City Engineer.

AUG. N. JOHNSON

SUCCESSOR TO NELS JOHNSON.

MANUFACTURER OF

SAW MILL AND SHINGLE MILL

Machinery

AND SALT WELL OUTFITS.

HEAD BLOCKS,
SET WORKS,
CARRIAGES,
STEEL RAILS,
SAW ARBORS,
BULL CHAINS,
CHAIN CONVEYORS,
JACK WORKS,
COLLARS FOR SHINGLE SAWS.

STEAM PUMPS,
STEAM FORGING,
GENERAL FORGING,
BEVEL FRICTIONS,
DERRICKS,
HOISTING ENGINES,
AND ALL KINDS
OF IRON WORKS.

FOUNDRY AND IRON WORKS.

. . . MANISTEE, MICHIGAN.

YOU

HAVE OFTEN heard the remark:

"Just as good as Dyckerhoff."

If **Dyckerhoff** is recognized as the best, as the standard, then why not insist on having **"Dyckerhoff"**?

Dyckerhoff costs a trifle more than other cements at first cost, but is cheapest in the end.

Its greater strength and absolute uniformity permit the addition of a larger proportion of sand, resulting in the cheapest and most durable work.

Unequalled for foundations, floors, sidewalks, etc.

Dyckerhoff

is for sale by

REMER BROS., Saginaw, Mich.
McLAUGHLIN & MAGILL, West Bay City, Mich.
SWITZER BROS., Flint, Mich.
ROBERT LAKE, Jackson, Mich.
A. B. KNOWLSON, Grand Rapids, Mich.
W. C. PAGE & CO., Ionia, Mich.
F. C. NOWACK, Menominee, Mich.
F. B. SPEAR, Marquette, Mich.
BRADY & CO., Detroit, Mich.

JACKSON & CHURCH,

SAGINAW, W. S., MICH.

. . . IRON WORK

FOR BUILDINGS,

HOISTING ENGINES,
BOILERS, TANKS,
ETC. . . . . .

WRITE FOR ESTIMATES.

R. D. WOOD & CO.,

Engineers, Iron Founders, Machinists.

400 Chestnut Street, PHILADELPHIA, PA.

Foundries and Works: Millville, Florence, Camden, N. J.

— BUILDERS OF —

Matthews' Single AND Double Valve **Fire Hydrants**

Gas and Water Works,
Gas Holders, Gas Machinery.

Eddy Valves, Freeman's Valve, Indicator Posts, Hydraulic Cranes, Presses, Lifts, etc., Turbines and Water Power Pumps.

EVERY DESCRIPTION OF CAST IRON PIPE.

Sugar House Work, Loam Castings, Heavy Special Machinery, General Castings.

This magazine is the foremost in the world devoted to municipal work. It has been said of it that "its volumes constitute the really valuable literature on the subject of municipal engineering." It received the World's Fair Award for excellence.

From Detroit Journal—PAVING AND MUNICIPAL ENGINEERING has been a large factor in an educational way in the remarkable progress in the improvement of cities.

From Philadelphia Press—PAVING AND MUNICIPAL ENGINEERING is itself a good example in enterprising and progressive work.

From Kansas City Times—PAVING AND MUNICIPAL ENGINEERING is the most helpful publication in America to all who are interested in public improvements.

From Boston Herald—PAVING AND MUNICIPAL ENGINGEERING is full of valuable technical and professional information.

From Sacramento (Cal.) Record-Union—Every municipal officer in the land ought to have and read PAVING AND MUNICIPAL ENGINEERING.

From The Tacoma (Wash.) Daily Ledger—The standard of PAVING AND MUNICIPAL ENGINEERING is high.

Every number contains special articles by leading authorities. It gives all current information on new methods and ideas. It answers questions from subscribers on technical matters. It contains the latest contracting news from the entire country.

A monthly magazine of 118 pages, illustrated.

Subscription—$2.00 a year; single copies, 25 cents: they are worth too much to be sent gratuitously. Address,

Municipal Engineering Co., 84-85-86 Commercial Club Bldg., Indianapolis.
275-A Washington Bldg., New York.

UNION AKRON CEMENT COMPANY

Sole Manufacturers of the

AKRON CEMENT

STAR BRAND

The Strongest Natural Hydraulic Cement Manufactured in America.

ESPECIALLY ADAPTED FOR BRIDGE ABUTMENTS, CONCRETE AND USE UNDER WATER.

Capacity of Works, 2,000 Barrels Daily.

OFFICE, 141 ERIE STREET, BUFFALO, N. Y.

DO YOU WANT A WATER TUBE BOILER

Absolutely Safe?
Using no Cast Iron in Construction?
The Most Accessible and Durable?
The Easiest to Clean and Repair?
Very Economical in Fuel?
Sold at Small Profit?

IT IS

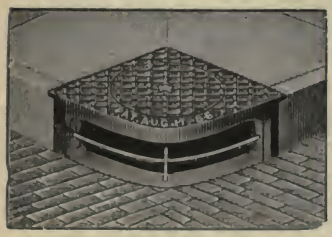
THE WOOD WATER TUBE SAFETY STEAM BOILER,

AS MANUFACTURED BY

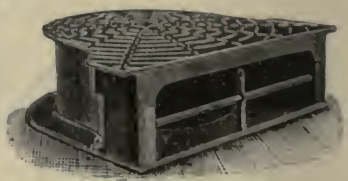
WICKES BROS.

SAGINAW, E. S., MICH.

SEND FOR CATALOGUE "MODERN STEAM GENERATORS"



SEWER INLET.



CATCH BASIN COVER.

MADE BY

H. W. McDonald & Son,

GALION, OHIO.

The Patent IRON STAR SEWER INLETS and CATCH BASIN COVERS are made with straight fronts or of ANY DESIRED RADIUS. Have 18 inch or 24 inch INTERLOCKING MAN HOLE LIDS, are supplied with REMOVBALE WROUGHT IRON GRATES with one or more horizontal and vertical bars, are NEAT, STRONG, DURABLE and guaranteed to give satisfaction. Special Radius Inlets and Catch Basin Covers made to order WITHOUT EXTRA CHARGE. *Inlets to fit any required size of Sewer Pipes and all depths of Gutter.*

Before purchasing imitations or infringements, you will find it to your interest to write us for illustrated catalogue and prices.

— USE —

"RELIABLE"

STEEL TAPE.

THE INCONVENIENCE OF OPENING WITH FINGER NAIL ENTIRELY DONE AWAY WITH.

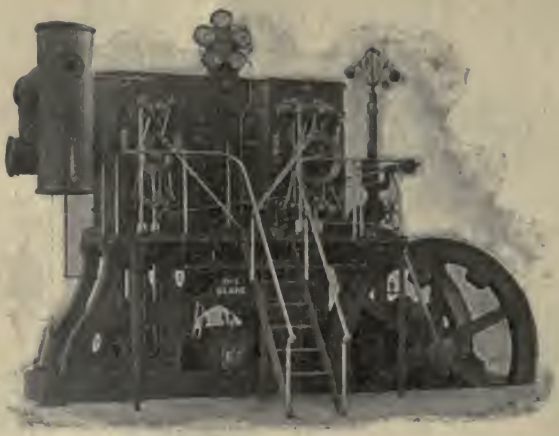
DOUBLE EXTENSION AND FOLDING HANDLE MAKES WINDING ONE HUNDRED PER CENT EASIER.

WE MAKE TAPES OF ALL STYLES

AND WILL BE PLEASED TO MAIL CATALOGUE.

LUFKIN RULE CO.,

SAGINAW, MICH.



Vertical Cross Compound High Duty Pumping Engine

BUILT BY

THE DEANE STEAM PUMP CO.

HOLYOKE, MASS.

MANUFACTURERS OF

HIGH CLASS PUMPING MACHINERY,

WHICH WE CAN FURNISH
FOR ALL REQUIREMENTS.

. . . Water Works Engines a Specialty . . .

COMPOUND AND TRIPLE EXPANSION.

DETAIL DESCRIPTION AND RECORD OF DUTY TRIALS WILL BE SENT ON APPLICATION.

WAREROOMS:

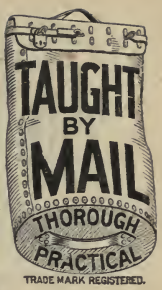
NEW YORK,
72 Cortlandt Street.

BOSTON,
54 Oliver Street.

PHILADELPHIA,
18 North Seventh Street.

CHICAGO,
199-201 Van Buren Street.

HYDRAULIC ENGINEERING



Civil Engineering; Municipal Engineering; Bridge Engineering; Railroad Engineering; Surveying and Mapping; Mechanics; Mechanical Drawing; Electricity; Architecture; Architectural Drawing and Designing; Steam Engineering (Stationary, Locomotive or Marine); Plumbing and Heating; Coal and Metal Mining; Prospecting, and the English Branches.

Civil Engineers can make wise use of idle time in reviewing their studies and in mastering other branches. Scholarships are not forfeited upon failure to pay installments promptly. Students make rapid progress in learning to Draw and Letter. All representations may be relied upon. Send for Free Circular and Book of Testimonials, stating the subject you wish to study, to

THE INTERNATIONAL CORRESPONDENCE SCHOOLS, Box 817, Scranton, Pa.

Fairbanks, Morse & Co.

CHICAGO.

HEADQUARTERS FOR LATEST DESIGNS IN

Gas and Gasoline Engines, Steam Engines, Pumps, Boilers, Inspirators, Valves, Tanks and Fixtures, Water Works Supplies, Railroad Appliances.

CATALOGUE FREE.

ULMER & HUFF,

Manufacturers of

Engineering, Surveying and Scientific INSTRUMENTS,

124 CHAMPLAIN ST. CLEVELAND, OHIO.

Makers of the New J. B. Davis Solar Transit. Agents for Lucas Tapes and Supplies.
Repairing done at reasonable prices and satisfaction guaranteed.

HAVE YOU EVER TRIED ? ? ? WHAT ? ? ?

TO MAKE YOUR BLUE PRINTS IN BAD WEATHER?

I believe you have and got very poor and unsatisfactory results in general.
Why not give my

New Lightning Brown Process Papers

A TRIAL?

THEY WILL RENDER THE MOST BEAUTIFUL PRINTS IN ANY WEATHER.
SUN OR NO SUN, CLOUDS OR CLEAR. ALWAYS.

JOHN F. SCHWANFELDER, Sole Mnfr., 451 Pearl Street, Cleveland, Ohio.

J. A. BALDWIN, President.
GEO. R. HILL, Vice President.

CHAS. BAIRD, Treasurer.
B. W. ROBINSON, Secretary.

THE UNION SEWER PIPE CO.,

DEALERS IN

STANDARD AKRON

Sewer Pipe,

THOROUGHLY VITRIFIED AND SALT GLAZED.

AKRON, - - OHIO.

MANUAL OF LAND SURVEYING.

By F. Hodgman, M. S. C. E., Practical Surveyor and Civil Engineer.

494 pages, printed on strong, light paper, and bound in morocco with flap. The Land Surveyors' Best Pocket Companion. Price, $2.50.

SURVEYORS' TABLES.

112 Pages	Being the Tables from the Manual of Land Surveying, bound separately.	Price $1

FIELD BOOK, for Surveyors.

Specially adapted to Michigan County Surveyors' Records.

Ruled in small cross sections, and having tables of Natural Sines, Tangents, Secants, Departures, Azimuths of Polaris, Radii and Deflections, Tangents and External Secants of a 1° Curve, Curve Formulæ and Traverse Table. Well bound in flexible leather with flap and pencil holder. Also bound in stiff covers without flap. Single copies, by mail, 75 cents; per dozen, by express, $7.00.

The above books published and for sale by

F. HODGMAN,
Sec'y Michigan Eng. Society,
CLIMAX, MICH.

THE DEANE
OF HOLYOKE.

Pumping Machinery.

Steam Pumps.

Power Pumps.

Single, Duplex, Triplex, Compound and Triple Expansion.

THE DEANE STEAM PUMP CO.

Holyoke, Mass. Boston Office, 54 Oliver St.

NEW YORK. PHILADELPHIA. CHICAGO.

THOMSON METER COMPANY,

79-83 WASHINGTON ST.

BROOKLYN, N. Y.

Water Meters Sold and Delivered in 1895,

14,076.

Increase over 1894,

1,262.

We stamp our Meters only as we sell them.

Whole number of Meters sold to April 18, 1896,

77,126.

CATALOGUE AND PRICE LIST FURNISHED ON APPLICATION.

THE MICHIGAN

ENGINEERS' ANNUAL,

CONTAINING THE

Proceedings of the Michigan Engineering Society for 1896.

PUBLISHED BY THE SOCIETY.
F. HODGMAN, SECRETARY, CLIMAX, MICH.

Copyrighted in 1896 by the Michigan Engineering Society.

80512
3/10/06

KALAMAZOO PUBLISHING COMPANY,
KALAMAZOO, MICH.

MICHIGAN ENGINEERING SOCIETY.

OFFICERS FOR 1896.

President, GEO. L. WELLS, - - - Bay City
Vice President, FRANK F. ROGERS, - - Port Huron
Secretary and Treasurer, F. HODGMAN, - - - Climax

DIRECTORS.

DORR SKEELS, - - - - - - Grand Rapids
WM. B. SEARS, - - - - - - Saginaw, E. S.
WM. APPLETON, - - - - - - - Lansing

MODERN METHODS OF SUPPLYING CITIES WITH PURE WATER.

BY ALLEN HAZEN,
MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

Mr. President and Gentlemen of the Society:

I was particularly glad to accept the invitation of your President to speak at this convention, for, although a native and resident of New England, I have had the pleasure of visiting frequently and of living for a limited period in the Middle and Western States, and I appreciate the fact that although your population has not yet become as dense as it is upon the Atlantic Coast, you still have many problems in water supply and sewage disposal of peculiar difficulty and interest; so that with the rapidly increasing populations of your cities, fields for professional investigation and work are opening up which are hardly equaled in the East.

It has been my good fortune during the past few years to have been able to visit an unusually large number of the water supplies of the great cities of Europe and America, and to become acquainted with many of the men most active in designing and executing the improvements and extensions of these supplies, and to become familiar with the methods which they use.

In visiting water works in different cities and in different countries, I have been continually impressed with the diversity in ideas in regard to water supply which are prevalent in different parts of the world, and it is often really marvelous, considering the international spirit of the last part of the nineteenth century, how many different local methods are used in a most satisfactory way, and which are yet hardly known, or at least are not properly understood, outside of the limited localities in which they are used. Thus the impounding reservoirs which

are so largely and successfully used in England and in portions of the United States, are hardly known upon the Continent of Europe; and the methods of securing ample and satisfactory ground water supplies, which have been brought to a high state of perfection in some of the countries in Continental Europe, have received but limited application elsewhere; and the processes of filtration of river and lake waters, which are used upon an almost gigantic scale in England, Holland and Germany, have received but little application in France and Austria, and are scarcely known as yet in the United States, least of all in the Middle and Western States, where from the geological and geographical conditions, filtration is most needed.

It is true that many methods of water supply have been developed to meet special conditions and are not applicable to other and different conditions, but at the same time, it must be admitted that a diffusion of information in regard to the various methods will often lead to the discovery that methods can be used with advantage in other localities than those to which they are now confined. This is particularly the case in the United States, where, with our enormous area, we have the widest range of conditions, and with them the opportunities to try the various methods of securing pure water.

The rapid growth of our cities and the limited capital at their command, have too often led our authorities to secure water from the nearest stream or lake without much regard to its quality, and although the methods which must be used in different parts of the country to secure pure water differ widely, no one will deny that in every state in the Union there is ample opportunity for the introduction of better methods in collecting the water so necessary to large parts of our population.

The rocky hills of New England have deep valleys between them which are often too steep and stony to be suitable for agricultural purposes, and are frequently located near manufacturing towns, where if they had been prepared expressly for that purpose, they could hardly have been better arranged as sites for impounding reservoirs. In the Middle States, with alluvial plains or slightly rolling country, impounding reservoirs

become difficult or impossible, but the large rivers of muddy water, which flow by nearly all of the great cities in that region, afford a splendid field for the adoption of the methods of filtration which have been so successfully used under corresponding conditions in Germany; and, in the far West, as well as in many localities scattered over the whole country, there are chances for developing ground water supplies similar to those which have been so successfully obtained on all sides of the Alps in Europe, in France, Germany and Austria, and like which we have nothing in the United States.

There are three principal methods of obtaining a good water supply for a city. The first, and in some respects the most satisfactory method, consists in drawing the water from the ground through which it has passed and in so doing has become thoroughly purified from the innumerable impurities which so often render surface water objectionable. In case the ground water discharges naturally over the surface it is called a spring water supply. In New England, even the largest springs yield only a quantity of water entirely inadequate for the supply of even small cities or towns, and our engineers hardly think of them in designing public water supplies; but in other parts of the world there are springs so large as to be adequate for the supply of even great cities. The largest city so supplied is Paris, with its population of two and one-half millions, which draws a minimum of fifty-three million gallons daily from springs located in three separate directions from the city at distances of from sixty to one hundred miles, while a new supply is contemplated from other and still larger springs twice as far to the east. Vienna also is supplied from springs having their origin in the snow-capped limestone mountains of the Semmering, sixty miles to the south of the city, and Munich has a magnificent supply from springs in the foot-hills of the Alps.

Many other cities are supplied with ground water taken from points where there is no natural overflow to the surface. In these cases the water was formerly collected by so-called filter galleries or collecting conduits often built near or parallel to rivers, but in the more recent works it has usually been

found better to substitute tubular wells for the filter galleries, for, as a rule, the water can be more cheaply collected in that way, and its flow can be more satisfactorily controlled.

Among the great cities supplied with ground water in this way are Budapest, which draws its water from wells along the Danube; Leipsic, which is supplied by an extremely interesting series of wells in an abandoned bed of the River Mulde; Dresden, with its filter gallery by the River Elbe, and Cologne supplied by wells near the River Rhine, and a considerable number of English cities supplied from wells sunk in the chalk, including a part of London where a population of nearly half a million is supplied in this way.

In the United States, ground water has been extensively used for supplying small cities and towns, and a few large cities have been wholly or partially supplied in this way. Brooklyn was originally supplied from wells and still derives considerable water from this source, although the water so obtained is mixed with pond and reservoir waters, so that the supply as a whole cannot fairly be called a ground water supply. Charleston, Memphis and Dayton are said to be supplied by artificial wells, and Los Angeles is supplied from galleries in the gravel near the Los Angeles River. Lowell has for years endeavored to secure a supply of ground water from wells near the Merrimac River and some of its tributaries, but owing to the limited quantities of water obtained, is still obliged to draw a considerable part of its water from the river. Among the smaller cities, Waltham, Newton and Brookline, in Massachusetts, are supplied from wells or galleries along the Charles River, and large numbers of the smaller cities are supplied in a similar way. But looking at the matter broadly, ground water supplies have not received anything like the attention which they deserve in the United States, and the supplies which we now have are not in any measure comparable to the magnificent European ground water supplies which I have mentioned.

The second method of obtaining a good water supply is from an impounding reservoir or natural lake upon an uninhabited or but sparsely populated water-shed. This is pre-emi-

nently the English method of water supply. Liverpool, Manchester, Bradford and Dublin have expended millons upon millions of pounds sterling in securing such water-sheds and in bringing the water so obtained through long lines of aqueducts to the respective cities. The supply for Liverpool, obtained from the magnificent dam upon the Vyrnwy River in Wales, seventy-seven miles from the city, is one of the best known of these supplies. Birmingham is commencing to develop a similar supply from a water-shed over eighty miles from the city, to furnish water for nearly a million people, and in London there are many persons desirous of going to Wales for a water supply, the estimated cost of which is one hundred and eighty-eight million dollars, although the persons desiring such a supply are undoubedly in the minority, and there is no immediate prospect that the present supplies from the Thames and the Lea will be abandoned.

New England, with conditions in many respects similar to those of old England, has largely followed English precedent, and the use of impounding reservoirs is the most common method of water supply in the New England States, and, in a measure also, along the entire Atlantic Coast. Boston, New York, Baltimore, and to a certain extent, Brooklyn, have long been supplied in this way, and the water supplies so obtained, from a sanitary standpoint, are the best of the great water supplies in the United States.

Among the most important works in the United States for developing supplies of this character should be mentioned the new Croton dam for New York, now in course of construction, and the Nashua River supply for Boston and its suburbs. Boston, as you know, has a population of about half a million and is surrounded by some twenty-seven suburbs within a distance of ten miles from the State House, having an aggregate population equal to the population of the city itself. Boston had nearly reached the limit of the capacity of its water supply and many of the suburbs were pressed for water to meet even their present needs, and the qualities of a number of the present supplies were not all that could be desired. The voluntary co-operation of so many separate municipalities in

securing a general water supply could hardly be expected, and to meet this peculiar condition of affairs, the State created a Metropolitan Water Board with full powers to borrow money to pay for the construction of a masonry dam upon the Nashua River, 150 high, which will flood an area 4,195 acres to an average depth of 46 feet, forming a reservoir with a capacity of 63 billion gallons. The Board is also authorized to construct the necessary aqueducts and pipe lines to convey the water to the various municipalities requiring it; and the expenses incurred, including interest on the debt and the payments to the sinking fund to retire the loan at maturity, are apportioned among the various municipalities taking the water in proportion to their respective wealths and populations.

The estimated first cost of this work is nineteen million dollars, in addition to which a part of the Boston Water Works will be taken and operated in conjunction with the new supply at an additional cost of one-third as much more. The appropriation of twenty-seven million dollars, made by the Legislature to carry out this work is, at first thought, somewhat imposing, but after a critical examination of the sums which in past years have been spent in extending the water works of the various municipalities, and the sums which it would be necessary to expend in any case in order to keep up the supplies, it is apparent that this cost is not excessive, and it is further found that the income from the sale of water in the district to be supplied is so great, that with the increase which can be reasonably expected, it will fully meet the interest on this cost, as well as the sinking fund necessary to retire the indebtedness at maturity, and the interest and sinking fund on the bonds now outstanding, without increasing the present water rates.

The method of securing good water supplies by impounding reservoirs is but rarely applicable in the Middle States, both because there are no corresponding areas of practically waste land free or nearly free from population, and because the country is so flat that impounding reservoirs of sufficient magnitude would involve so much shallow flowage that a good quality of water could not be expected from them.

For the cities in this region which are also from their position unable to secure an adequate supply of ground water, the third method of securing a pure water supply, namely, by means of filtration, is almost the only one which can be used.

The subject of filtration* has, within the last few years, commenced to attract a good deal of attention in America, and it is often supposed that it is a comparatively new and almost experimental method. It is new to the United States, but not to the world. As long ago as 1839, sand filters were built to filter a portion of the water supplied to London, and the process was so successful that its use rapidly extended until all the water for London and for numerous other English cities was filtered; and in the fifties, filter plants commenced to be constructed in Germany. In 1876 it was reported by a Commission investigating the subject, that there were over one hundred places in Great Britain that systematically employed sand filtration to purify their water supplies. Since that time the use of filtration has steadily and rapidly increased.

Sometime since, I prepared a list of certain European cities in which I knew that sand filtration was employed for purifying the public water supplies, and the aggregate population of these cities exceeded fifteen million people by the last census, although I did not include a large number of other cities in which filtration is undoubtedly used but in regard to which my information was not complete, nor the hundreds of smaller cities, the names of which it would often be impossible to obtain. Taking this into account, it is by no means an excessive estimate that over twenty millions of people in Europe are now regularly supplied with filtered water. It is difficult to properly appreciate the magnitude of this number, but some conception of it can be obtained by stating that it was nearly equal to the aggregate population of all cities and towns in the United States having public water supplies from all kinds of sources, in 1890.

A process which has been so widely used can hardly be called an experimental process, and you will not be surprised

* The construction of filters, their theory, operation and results, have been fully treated by the author in the "Filtration of Public Water Supplies," John Wiley & Sons, New York, 1895.

when I tell you that so much information has been obtained in regard to it that filters can be built with just as great confidence in the results to be obtained from them as would be felt in the success of a masonry dam to hold back the water of a brook.

Among the great cities supplied with filtered water may be mentioned London, where five million people are supplied with two hundred million gallons of water daily, filtered through one hundred and twenty acres of sand filters, not including the considerable population supplied from wells in the chalk; Berlin, where one million six hundred thousand people are supplied with filtered water drawn from the two rivers flowing through the city; Liverpool, where nearly a million people are supplied with filtered water, most of it drawn from the impounding reservoir mentioned above; Hamburg, with a population of six hundred thousand, supplied with filtered water drawn from the much polluted River Elbe, as well as the great cities of Amsterdam, Rotterdam, Birmingham, Leeds, Bradford, Breslau, Madgeburg, Warsaw, St. Petersburg, Copenhagen and Antwerp.

In England, Holland and Germany, a majority of the inhabitants of all great cities are supplied with filtered water, and those not so supplied are, with few exceptions, supplied with ground water, which is also filtered water, although filtered by natural instead of artificial processes.

The objects of filtration are two-fold; it removes from turbid waters the mud and disagreeable tastes and odors which they so often contain, and renders them attractive and palatable, and for this reason, even if there were no other advantages to be obtained, filtration would be desirable and often worth more to a city than its cost. But there is a second reason for filtration which affects even more directly the welfare of our cities, and that is, the great improvement in their health which may be anticipated, and in fact, which has actually resulted from the introduction of filtration. The cases in which this improvement has been noticed are so numerous that I should tire you if I attempted to give you an account of even the most important of them, but you will permit me to mention a few of the most important cases.

London draws its water supply from two small and much polluted rivers, the Thames and the Lea. The populations per square mile upon the water sheds of these rivers are much greater than upon those of the Merrimac, or the Hudson, or the Allegheny, or the Ohio, or in fact, than upon almost any American stream used for water supply. Many years ago, water was used from these streams without filtration, and London suffered as severely from typhoid fever, cholera, plague and other diseases which may, and probably did, have their origin in the water, as any other city; but since the introduction of filtration, there has been so great an improvement in the health of the city that the death rate from typhoid fever is lower than in almost any American city, and cholera has only made its appearance to any considerable extent since the use of filters, on one occasion, that being in the early sixties, when it was found by investigation that the outbreak followed the temporary failure to supply filtered water by one of the water companies, and the outbreak was nearly confined to the area which received water from that source.

Hamburg, in 1892, was the only city in Germany, and in fact, almost the only great city in Western Europe, that used unfiltered river water for its public supply, and it was no accident that it was Hamburg, and Hamburg alone, that suffered severely from cholera in that year. This outbreak resulted in one month in over twenty thousand cases of cholera and eight thousand deaths, and was directly attributed to the use of unfiltered water from the polluted river Elbe. At the same time, Altona, a city immediately below Hamburg upon the river, and so near as to be connected with it by several lines of street cars, on which the fare from one city to the other is only two and one-half cents, drew its water supply from the Elbe, but at a point lower down where it was subject not only to the pollutions that affected Hamburg's water supply, but where it had also received the entire sewage of both Hamburg and Altona, and notwithstanding this most unusual amount of pollution, the water was so thoroughly purified by filtration before being supplied to Altona, that the inhabitants of the city remained substantially free from cholera.

excepting the few cases directly imported from Hamburg. This case is particularly instructive, for the river Elbe, at Altona, had received the sewage from at least six million people living in large cities, and not including the populations of the smaller towns and country districts which are not sewered; and at this time, owing to the twenty thousand cases of cholera in Hamburg, it must have contained an extraordinary number of the bacteria which cause cholera, and the fact that cholera gained no foothold in Altona, beyond a limited number of cases, most of which were directly imported from Hamburg, is conclusive proof of the value of filtration in protecting the health of a city.

Breslau, Berlin, Schiedam, Antwerp and a hundred other cities draw their water supplies from sources polluted even more seriously than those which are properly regarded as so objectionable in the United States, but filter them, and afterwards supply them to populations having uniformly such low death rates from those diseases which are ordinarily conveyed by drinking water that they are hardly equaled in this respect by even the most healthy cities of the United States.

But it is not necessary to go outside of our own country for illustrations in this line. The cities of Hudson and Poughkeepsie, in New York, take their water supplies from the Hudson River, upon which they are located, and notwithstanding the pollution of that river, which has caused repeated epidemics of typhoid fever in Albany, where the water is used in its raw state; these cities taking their water from the same source and filtering it, have been constantly protected from water-carried diseases. A yet more striking case is furnished by the City of Lawrence, in Massachusetts, which three years ago constructed a filter for the purification of its public water supply. This filter, although following in its general lines the forms used in European filters, was the direct result of the investigations of the Massachusetts State Board of Health at its experiment station in Lawrence, of which I had the privilege of being in direct charge for nearly five years, under the direction of Mr. Hiram F. Mills, to whose devoted energy and foresight are due both the experiment station and the filter for the public water supply of the City of Lawrence.

Prior to the construction of the filter, the city had had a death rate from typhoid fever which was exceeded by only a few of the larger cities in the United States, and this death rate was directly attributed to the use of the river water polluted by the sewage from the numerous cities upon its banks. Cases of typhoid fever in Lawrence were continually present for many years, and continued up to the time that the filter was put in operation. For six years before this time there were, on an average, over fifty deaths annually from this cause, and the numbers were very constant, ranging only from forty-seven to sixty for the various years. After the filter was put in operation there was a prompt and decisive drop in the death rate, which has ever since been but a mere fraction of that which had formerly existed, and of the deaths that still occur in Lawrence from this cause, a large proportion are among operatives in some of the mills where unfiltered river water is used for washing purposes, and in spite of the rules to the contrary, conspicuously posted in every mill, some of the opratives continue to use the water for drinking.

Dr. Copeland, Biologist at the Lawrence Experiment Station, has kindly secured for me a statement of the deaths from typhoid fever during the time since the filter was put in operation. For the year 1894, there were twenty-four deaths, of which twelve were among people who were known to have drunk the unfiltered river water, and four others were supposed to have contracted the disease out of town, and in 1895 there were sixteen deaths, nine of which were of people who were known to have drunk the unfiltered river water. Even with these cases included, the number of deaths for the past year is thus less than a third of what it was before the commencement of filtration, notwithstanding the increased population.

It may be taken as a conclusion from European experience, as well as from the results at Lawrence, that properly constructed filters, operated in a suitable manner, will remove nearly all of the disease producing qualities in the raw waters now in use by so many of our cities, and will affect very great reductions in the death rates from diseases capable of being carried by water.

A question which you will ask is what such filtration costs and whether it is worth the price. I have recently been engaged in making plans and estimates for a very large system of filtration, which was proposed as an alternative to the impounding reservoir project which has been adopted for the supply of the city of Boston and its suburbs. It was proposed to take the water from the Merrimac River above the city of Lowell, where it is less polluted than it is at the point where it is taken for the supply at Lawrence, and to purify it by filtration and to deliver it to the city by pumping. This project involved the construction of thirty-two filter beds having effective areas of one acre each, and covered by vaulting as a protection against frost, the total estimated cost of these beds, with the necessary appurtenances, being $2,180,000. It was proposed to increase the filtering area from time to time as required by the growth of the city, and plans were made for the ultimate construction of eighty acres of filter beds.

The total cost of the acqueducts, reservoirs, pumping machinery and land damages required for this project, together with the capitalized cost of pumping and operating the filters, amounted to $17,463,000, or about 92 per cent. of the cost of providing a corresponding supply of unpolluted water from the Nashua River, and it was thought that the natural purity of the latter supply, and the greater security in operating the system, more than offset the difference between the costs of the two projects, and the gravity supply was therefore adopted.

Although this work will never be executed, the estimates which were prepared with great care, have allowed me to accumulate considerable information with regard to the cost of filtration on a large scale at current American prices. This cost of filtration will differ widely with local conditions, and it is impossible for me to give you an estimate which will be correct under particular conditions, but for moderate sized cities, it seems probable that the cost of filters will rarely exceed $3.50 per inhabitant, and the running expenses, including the interest on the cost of construction and the payments for sinking funds upon the same basis, will not exceed 35 cents per inhabitant annually, and where the local conditions are quite favorable,

figures materially lower than this estimate may be anticipated. Putting the same thing in another way, it may be said in a general way, that the cost of filtration will add about ten per cent. to the cost of water as now supplied, although the percentage increase would be greater than this where water has been pumped at a minimum of expense from an improper source in the immediate neighborhood of a city.

We must now consider the question as to whether or not the advantages to be secured are equal to this cost. Great engineering works like the construction of filters will not be undertaken to save a single life nor to prevent a dozen cases of fever. It must be shown that the advantages to be obtained are comparable with the expenditures involved, upon something the same basis that would be used in discussing the merits of other life saving devices, or of the abolition of grade crossings.

The injuries resulting from the use of impure water are many. To call your attention to only a few of them, I might mention the objectionable appearance, taste and odor of such water; the causation of diarrhœa and other minor diseases, which are hardly noticed upon the mortality reports, but which are none the less uncomfortable for the people suffering from them; the losses, direct and indirect, resulting from typhoid fever in a city, loss of time for those suffering from it, doctors, nurses and hospital bills and the loss of the lives of those dying. Then there is the danger from cholera, and while we hope that this dread disease will not again gain a foothold on our shores, we know from all past experiences that should it do so, it would attack the cities with polluted water supplies, and we should gladly pay for purifying such supplies for much the same reason that we pay insurance rates to protect ourselves from a great and terrible, although remote danger. To consider all of these causes of loss resulting from bad water would require too much time, and I shall for the present throw out all but one of them, namely, the loss from deaths by typhoid fever.

Typhoid fever is essentially a disease of youth and early middle age, a very large majority of the cases being of people between fifteen and fifty years of age. It is also a disease of

all classes, affecting the rich as much as the poor; in fact, it sometime seems as if it had less foothold in the slums than elsewhere, where some of our recently arrived brothers from foreign shores are so accustomed to filth in every form, that they are apparently impregnable to the typhoid germs.

Taking these facts into consideration, we shall not be inclined to estimate the value of the lives lost from this cause at less than $5,000 each, and if we take this estimate, and the cost of filtration as given above, we shall find that from a purely financial standpoint, filtration will pay in a city where it effects the reduction of seven deaths annually per 100,000 of population, and in a case where the reduction amounts to seventy cases, the saving will pay for the cost of the filters in a single year. Upon this basis, according to the census of 1890 there were five cities in the United States with populations of over 50,000 each, and with an aggregate population of 690,760, which used unfiltered surface waters and had so many unnecessary deaths from typhoid fever, that at $5,000 each, the saving due to filtration would have paid for the entire cost of filtration in the first year that the filters were in use. In addition, there were sixteen other cities with an aggregate population of 3,717,560,where filtration would have paid for itself in two years or less, and still eighteen others with an aggregate population of 3,238,617, where filtration would have saved seven or more lives annually per 100,000, and would have more than paid for the interest and cost of operation of filters upon the basis given above. These estimates are upon the very liberal assumption that twenty-five deaths from this cause are inevitable, or rather that this number would result from importations from less healthy neighbors, and would occur with ever so good a water supply under present general American conditions.

Some of these cities may have been influenced by unusual local conditions in 1890. Others have in one way or another improved their water supplies since that date, and there are several cities in which the present death rates are materially lower than those given in the census. On the other hand, it is equally true that a number of cities, including some of the larger ones, have since that year had severe epidemics of

typhoid fever, which have given very much higher rates than those of 1890. These fluctuations change the order of the cities in the list from year to year, but they do not change the general facts, which are as true to-day as they were in 1890.

Nearly all of the great cities of the United States are supplied with unfiltered surface waters, and a great majority of the waters are taken from rivers and lakes at points where they are polluted by sewage. The death rates from typhoid fever in these cities, whether they are compared with better supplied cities in this country or with European cities, are enormously high. Such rates were formerly common in European cities, but they have disappeared with better sanitary conditions. The introduction of filters has often worked marvelous changes in Europe, and in Lawrence the improvement in the city's health was prompt and unquestionable, and there is every reason to believe that the general introduction of better water in American cities will work corresponding revolutions.

The conditions in the United States have been somewhat exceptional. The growth of our cities, particularly in the west, has been phenomenal, and in the urgent necessity of providing a water supply ample in quantity, the equally important question of quality has been all too often overlooked. But this condition of affairs cannot last. Many of our cities are beginning to realize the need of better water, and the comparatively small opposition to a twenty-seven million dollar project for supplying Boston with water, several million dollars of which are directed towards securing a high quality of water as distinct from quantity, is evidence that we are moving in the right direction, and we may confidently expect that when the need of pure water is more generally known and felt by the American people, and when it is realized that the methods of securing good water supplies are comparatively well known and are quite beyond the experimental stage, we may confidently expect that our cities will abandon the filthy and unhealthy practice of using unfiltered river and polluted lake waters, and will put the quality as well as the quantity of their supplies up to standards not exceeded by those of any country.

The President.—Gentlemen, the paper is before you for discussion. Inasmuch as there has been a great deal of interest manifested by the citizens of Saginaw in this paper, and as they are here in considerable numbers to-night, the discussion will not be limited to the members of the society, and any gentleman who feels himself at all interested in this subject, is at liberty to discuss it or to ask questions to draw out the fullest possible discussion of the paper.

Mr. Williams.—The gentlemen seem to be waiting for some one to break the ice. Perhaps I have as good a right to do it as anyone. As far back as I can remember, almost ever since the introduction of the water-works systems in these two cities, there has been occasionally, periodically, we might say, some expression of desire for a better supply of water. The people of the East Side did much better than their neighbors on the West Side in locating their intake, but I do not think there are many citizens of Saginaw who care to drink even the water here. The chief end and aim of these water supplies seem to be to get water to sprinkle lawns and put out fires. I think I am safe in saying that the majority of the people of this city are supplied with wells of one form or another, and I think I am also safe in saying that there have been many dry wells this summer, and if you go to your physician, I am satisfied he will tell you that there has been more typhoid fever this season than is usual. If you look in various treatises on typhoid, you will find it maintained that whenever there is an extreme drouth there is a high death rate from typhoid fever, and it has become a proverb that low ground water is synonymous almost with a typhoid fever epidemic. Typhoid has raged extensively in all parts of the State this year. In the state of Massachusetts where most careful investigations have been carried on, and where the great majority of people obtain water from public supplies, the statement is made, after a careful review of the statistics, that they found no great difference between those years in which there was extreme drouth, and those years when there was an excessive rainfall, which goes to show that the matter of drouth affecting the development of typhoid fever, is largely due to the use of surface wells.

There are many citizens of Saginaw who believe that an abundant water supply could be obtained by the sinking of deep wells in this city. There are many wells about town which have been sunk from 90 to 125 feet and have obtained quite an abundant supply of good water. There is, I believe, on record, an account of one or two wells, struck accidentally, in which this stream flowed at the surface, but as the parties who were drilling for these wells were drilling for something beside fresh water, it was not investigated, and would probably be difficult to find again. On the other hand, many of these wells have not found this vein of water which is supposed to underlie the city, and it becomes a grave question to know whether there is a sufficient quantity of water in the strata underlying Saginaw, to supply it with the amount of water necessary for the uses of such a city. Of course there are plenty of places in the world where larger cities than Saginaw are supplied with ground water, but very few correspond in topographical and geological conditions with Saginaw. But we have the three rivers, uniting above the city, with a drainage area of 3,600 square miles. While you have had low water here, I think there is no one who dares to say that it was impossible to take from the Saginaw River all the water that these cities could legitimately use. Mr. Hazen has indicated the methods that should be applied to this water to render it as good as from deep wells. I have taken occasion to look into the matter a little, in order to estimate what it might cost your city to provide itself with water taken from the Saginaw River, at any point which might be convenient. I have been perhaps, somewhat sanguine as to the growth of Saginaw, and thought possibly you might want to provide for 100,000 people; but when we look back at the growth of some other cities, (Detroit for instance that in 1886 had but 100,000 and now has nearly 300,000), I see no reason why you might not anticipate that at some time in the future you might be called upon to supply 100,000 people.

In determining upon a water supply for the city, the first thing to decide is, how much water are you likely to want. Careful experiments have been carried on in the East and the

consensus of opinion is that 100 gallons per capita per day is sufficient; Detroit uses about 150 gallons, but from some investigations which I have made, I am well satisfied that 75 gallons per capita covers every drop of water employed for useful purposes there. To be on the safe side, we will take 100 gallons per capita per day, and we will assume 100,000 population, and that will call for 10,000,000 gallons per day. Now it is found that in hot days in summer, the consumption may exceed by 50 per cent the average, so that it will be necessary for you to provide for an additional 5,000,000 gallons in times of emergency, either by storage or filtration, I assume that you will provide a filtration area sufficient to filter this amount per day, which at most approved rates will require about seven acres. In addition to seven acres of land for filtration, you will need three acres for storage; I assume that land suitable can be purchased in the neighborhood of your East Side works at about $1,000 per acre; it may be I am too low—

(A voice, interrupting, "Take off nine hundred dollars,") (continuing)—Perhaps if the city wanted it, the price might go up.

Now Mr. Hazen, in his work on the Filtration of Water Supplies, published by John Wiley & Sons, New York, has furnished some statistics as to the cost of water filters, and I have taken from it an average price of $30,000 per acre, and I have allowed $20,000 per acre for your reservoir, and an additional $20,000 to take care of such additional pumps as might be necessary, and it gives a total of $300,000 investment to provide a filter plant. The interest on this, provided your bonds are floated at 5 per cent, would be $15,000. The operation of your filter, taking the average of 10,000,000 gallons per day, would cost $15,000 a year more. Your pumping during the past year, has cost you $12.00 per million gallons. At this rate, to pump the supply estimated would cost $56,000. The interest on the present indebtedness of your works, as I obtained it from the report for 1893, is about $26,000. I add an allowance of $20,000 per year for extensions and $28,000 for the sinking fund, to take care of the bonds which are now falling due, and those that would have to be issued in

the event of your introducing such a supply, and we have a total annual expense of $160,000. Now 100,000 population represents 20,000 families, and on this basis, the average per family assessment, to raise this revenue, would be $8.00. In the city of Detroit last year, it was $8.34. In 1886, when Detroit had 100,000, the average assessment was $10.23.

Now for the benefit of those who will say that I have assumed entirely too high figures for your population, I will drop it to a figure perhaps more nearly in consonance with what you will admit as probable, and take 60,000. The average family assessment for providing a supply for this number of people would be less than $10.00 per annum. In view of these facts, it seems to me that there is no reason why Saginaw should not have as good a supply of water as any city in the world, and why that department, which is now a continual drag upon your tax payers, taking out about $30,000 a year from the general tax levy, should not be made a self supporting institution. In Detroit we are continually having a surplus, which is only avoided by reducing our rates. There is no reason why Saginaw should not have a thoroughly self supporting system; if you give the people here water that they can use in their houses without fear th-re is no question but that in a short time it will be in universal use.

(Applause).

The President.—I believe that Prof. Greene has interested himself in this subject to some extent.

Prof. Greene.—(No response, being interrupted by the—

Question.—I would like to ask Mr. Hazen if this filtration must take place solely through sand?

Mr. Hazen.—Other substances have been suggested, but I do not know that they have been successfully used on a large scale. In Europe all of the public filtration plants use sand for the filtering material. The objection is sometimes raised that sand of suitable quality cannot be easily secured, but as a matter of fact, I do not think any alarm need be felt on that ground, because there are methods of preparing the sand from mixed materials at reasonable expense; and along the great lakes and greater rivers of the country there are sand beds that

are in every way suitable, and if sand cannot be found in one locality, low freight rates can be secured which will allow the sand to be brought from the points where it is available.

Filtration is undoubtedly somewhat expensive, but some of us who have been studying the problem have come to the conclusion that the benefits obtained from it are very great, and that the American people are wealthy enough to be able to afford it, and to secure pure water in that or some other way which yields an equally healthy supply.

The President.—Are there any other questions? During the last few years I have been forced into the study of water supply to some extent and in looking over the subject of filtration, it has occurred to me as being simply a matter of straining, which involves to a large extent the size of the vegetable matter in the water to be taken out, and the size of the particles in the sand filter. As Mr. Hazen has had a great deal to do with these filters, I would like to have him develop that point somewhat.

Mr. Hazen.—The effect of the process of filtration is a dual one. It is in part a straining process, and in part a biological action.

The properties of the water which cause disease are, for the most part, I might say almost exclusively, the bacteria in it. The bacteria which are objectionable are roughly about one ten-thousandth of an inch long. The solution of the problem of straining them out by passing the water through a material composed of particles so small that the bacteria would be unable to pass through its pores is almost impossible, but it is a property of sand that when water is passed through it, it accumulates upon itself masses of bacteria, not necessarily injurious bacteria, for there are many kinds, and these accumulations form on the sand grains a sort of jelly in which the bacteria in passing become entangled and held until they are destroyed and oxydized. There is always air in solution in the water and the organic matters always present are attacked by the organisms upon the sand grains, which live on such organic matter in the water and destroy it, so that the process

of filtration consists in a large measure of the destruction, or as we may call it, a sort of burning up of these matters.

The process of filtration, however, is something more than straining; it accomplishes results that could not be accomplished by straining, and in the filters at Hamburg and Berlin, it is found by actual tests that the bacteria are often eliminated to the extent of more than 99.9 per cent, and considering the minuteness of the organisms in comparison with the sizes of the passages between the sand grains we can see that there is something besides simple straining going on.

Mr. June.—I would like the gentleman to go a step further and state whether ultimately this process of consumption of which he speaks will be continuous, or whether in the course of time these filters will become so clogged that they will need to be removed?

Mr. Hazen.—A large part of the organic matter is absolutely destroyed, but of the more stable matters retained in the sand the great bulk are retained in the upper layer, and at intervals this upper layer is removed. At Lawrence half an inch is taken off six times a year. The sand can be washed and used again if desired. The body of the sand remains pretty nearly in its original condition. It is even more efficient as a filter after it has been in use for a time, than at first. So after a filter has been in use for a year or so, it ordinarily gives a slightly better result than it did in the beginning. Whether the sand would last forever or whether it would be necessary to replace it after ten or twenty years, depends largely upon the treatment it receives and is really a matter of minor importance, because the more expensive parts of the filter, that is the walls, bottom, regulators, conduits, etc., remain in any case. As a matter of fact, filters have been in use in London since 1839, nearly 60 years, and when the sand has been replaced, it has been at long intervals, and the expense is not serious.

The President.—I would like to ask if it has not been found in the tests that have been made, or are now being made at Lawrence, that the bacteria found in the water

are less at the extreme end of the system than right near the works where the freshly filtered water is pumped.

Mr. Hazen.—That is true. Before the water was filtered ninety per cent of the bacteria were removed by sedimentation or died natural deaths in the reservoir and in the mains; but notwithstanding that reduction, the ten per cent that remained were enough to give the city a death rate from typhoid fever not to be envied. Since the filter was put in operation, it has removed perhaps ninety-nine per cent. of the bacteria, and while the numbers cannot be computed accurately because they are so small, yet probably nine-tenths of the remaining ten per cent are removed as before, in the reservoir and mains, so that the water now used contains only one-tenth of one per cent., where formerly it contained ten per cent. These reductions in the numbers of objectionable bacteria are somewhat obscured by the growth in moderate numbers of certain harmless forms of bacteria, which while not injurious in any way, mask the actual removal of the objectionable forms.

The President.—Has a limit been put upon the number of typhoid or other germs allowable in a given quantity of water?

Mr. Hazen.—There are no set rules in regard to that. In Germany there has been an arbitrary rule that the number of bacteria per cubic centimeter should not exceed 100, corresponding to about one hundred thousand in a quart, but the bacteria in water are by no means all injurious; if they were it would be dreadful to think of what might happen. As a matter of fact, it is an extremely small proportion of them that are injurious. The injurious ones are generally from sewage. The other bacteria which are present in vast numbers are not injurious, and the life and growth and numbers of these harmless forms depend upon a whole chain of circumstances. In the United States, with our higher summer temperatures, these harmless forms often multiply rapidly, and a good many more than 100 per cubic centimeter will often occur without giving cause for alarm. This is a question which must be approached with great care.

Mr. Rogers.—As we have been highly instructed and entertained by this paper of Mr. Hazen's, I move that we extend to

him the heartfelt thanks of the society. Motion receiving support was unanimously carried.

The President.—Mr. G. S. Williams of the Detroit Water Works, whom we have heard to-night on the discussion of this paper, has announced that his paper, which is on the program for to-morrow morning, will be "The Purification of Water," which seems to be a continuation of the subject before us to night, and we invite the citizens of Saginaw to come in and hear this paper also.

Mr. June.—I would like to ask Mr. Hazen in connection with this matter, what kind of water this is, which they filter, is it spring water?

Mr. Hazen—It is hardly necessary to filter spring water. That and other ground water supplies are almost invariably of such excellent quality that any expenditure to filter them would be money thrown away. The waters purified in Europe are river or lake waters. The waters of a number of lakes, not very different in quality from the waters of the great lakes, are filtered, and the water of rivers is almost invariably filtered before being used.

There are two classes of river water; one of them from rivers like the Merrimac in Massachusetts, the Thames in England, and the Hudson in New York, where the water has but a comparatively sluggish flow and carries but little sediment; but in the waters of the rivers mentioned there is a good deal of sewage and the water is injurious to health; and the other class of water from rivers, where there is a rapid current, and the water carries large quantities of sediment. The German rivers are almost all of this latter class. The waters from Hamburg, Bremen, Breslau, Stettin, Magdeburg and other cities are all drawn from rivers of this character which are not only muddy but polluted. In these instances it is found necessary to remove part of the mud by sedimentation, allowing the heaviest matters to settle before filtration, in order to reduce the cost of filtration, as otherwise the particles of mud would clog up the filters too rapidly, making a more frequent change of sand necessary.

The President.—If there is nothing further to be brought before the society this evening, a motion to adjourn will be in order.

Mr. Roberts.—I believe it would be quite proper for the citizens of Saginaw also to extend a vote of thanks to Mr. Hazen for this very able paper, and I desire to make a motion that the citizens extend a vote of thanks to Mr. Hazen as well as to the Michigan Engineering Society. Motion supported.

Mr. Blank.—In addition to that I would like to state that there have been a number of analyses made of the Saginaw water, and it has been condemned, and I am heartily glad that this article has been presented, to help educate the people in a knowledge of the danger in which we are. I heartily endorse the motion.

Carried unanimously by vote of the citizens of Saginaw who were present.

THE PURIFICATION OF WATER.

BY G. S. WILLIAMS,
CIVIL ENGINEER OF DETROIT WATER WORKS.

This paper also read before the Detroit Association of Graduate Engineers of the University of Michigan.

I have been led to the selection of this subject by the many erroneous ideas prevalent regarding both the methods of purification and the necessities for its application, and also by the very frequent indifference to the conditions which prevail in connection with public water supplies in general. In this paper no claim is made to originality—even in the method of presentation—and the bulk of the matter herein contained may be found in much more extended form in the excellent reports of the Massachusetts State Board of Health from 1887 to the present time.

It may be of interest to note that in Massachusetts above all other states, is the engineer accorded that consideration which the profession receives abroad and so truly merits here. In that state no commission having to deal with engineering subjects is considered complete without its engineer member. The feeling on this point was amply demonstrated in the selection of the Metropolitan Water Supply Commission last spring. Governor Greenhalge nominated on this commission three gentlemen whose qualifications as citizens could not be questioned, but the Legislature, after confirming the first two nominees, declined to confirm the third because none of the three were engineers. As a result the commission comprises among its members Mr. John R. Freeman, one of the best known hydraulic engineers in New England. Engineers are also to be found on the Railway Commission, the Highway Commission, the Metropolitan Sewerage Commission, and last but not least, the Board of Health. On the last named board, Mr. Hiram F. Mills, C. E., for years engineer of the Essex Milling Co. of Lawrence, and more recently the successor of

the late renowned James B. Francis, in charge of canals and locks at Lowell, has done probably more than any other member in the carrying out of those special lines of investigation which have made this board an authority, not only in America, but the world over. By his influence the Hydraulic Laboratory of the Essex Milling Co. was obtained for the use of the Board as an experimental station; and without compensation, at the sacrifice of a lucrative private practice, he has devoted much of his time to the work of experiment and has brought to it the keen insight and technical knowledge developed by a lifetime of hydraulic work, which has contributed most abundantly to its success.

This board called to its assistance among others, Dr. Thomas M. Drown, then Professor of Chemistry in the Massachusetts Institute of Technology and now President of Lehigh University; William T. Sedgwick, Professor of Biology in the Massachusetts Institute of Technology; Frederick P. Steers, now Chief Engineer of the Metropolitan Water Board; Albert F. Noyes, now a member of the Metropolitan Sewerage Commission, and Wm. M. Brown, now the Chief Engineer of the last named commission, Mr. Allen Hazen, Mr. Geo. L. Fuller, now in charge of the Louisville filtration experiments, as well as many other specialists of note.

I am further indebted in the preparation of this paper to the excellent treatise on "The Filtration of Public Water Supplies," by Mr. Allen Hazen, and to a paper read before the Engineer's Club of St. Louis, by Mr. Robert Moore, and published in the "Journal of the Association of Engineering Societies" for January, 1895, and also to the recent work of Professor and Mrs. Frankland, "Micro-organisms in Water."

It is an old dictum that running water purifies itself, and some have so far developed this theory as to state that the water of a flowing stream is completely purified in twenty miles. In spite of the revelations of the observations and experiments of the past ten years there are many today—waterworks men among others—that will stoutly maintain the theory, and I have known of one case where the representative of a water company contended that six miles flow was suffi-

cient for purification when the decaying remains of a diseased cow were found in the water about seven miles above the intake of his works. In the light of recent investigations no more misleading doctrine in connection with water supply was ever foisted upon an innocent and unsuspecting public, unless it be that chemical analysis alone is sufficient to determine the wholesomeness of a water to be used for domestic purposes. These twin heresies, bred of the same original error, are so intimately connected that their discussion will be undertaken together. The impurities found in flowing water comprise certain inorganic or mineral substances in suspension, usually harmless, and more or less decayed organic matter of both animal and vegetable origin, partly in suspension and partly in solution, in itself not dangerous, together with microscopic living organisms both animal and vegetable, and lastly bacteria, organisms so small that with the most powerful microscopes we can barely distinguish them. As an example, the typhoid bacillus magnified 1100 times is not so large in body as our common house fly. The inorganic matter is made up of potash, soda, lime, magnesia, iron and alumina in combination with chlorine and carbonic, sulphuric and silicic acids. The organic matters are composed of carbon, nitrogen, oxygen and hydrogen, animal matters containing more nitrogen and less carbon than vegetable matters.

The process of decomposition in the organic matter takes place as follows: The carbon is first oxydized by the oxygen from the air mingled with the water, the resulting compounds being ammonia and carbon dioxide, next the ammonia is oxidized to nitrous acid and this is again oxidized to nitric acid, which, combining with the mineral constituents, forms a nitrate and ends the process. So far as the conditions of this process are concerned the chemical analysis tells us with fair accuracy in what stage the matter in the water may be, but it fails entirely to indicate the presence of those minute living organisms which constitute the real source of danger in drinking waters.

The results of a chemical analysis as usually given show: 1, the quantity of chlorine; 2, the amount of so called free

ammonia; 3, the amount of albuminoid ammonia; 4, the amount of nitrites; 5, the amount of nitrates; 6, the amount of fixed residue remaining after heating to a dull red with sodium carbonate; 7, the loss by so heating, and 8, the amount of oxygen consumed when the sample is boiled for a fixed length of time with permanganate of potash.

The chlorine, in itself harmless, if in excess of the normal quantity in waters of the particular locality, indicates previous sewage pollution.

The *free ammonia* which, however, is almost never *free* as the hydrate but is ordinarily the chloride or carbonate, and the nitrites, harmless in themselves, indicate organic matter in a state of partial decomposition. As *free ammonia* is a prominent constituent of sewage, it has been claimed that this is an evidence of sewage pollution, but high *free ammonia* is often found in waters in which there is no possibility of sewage pollution, so we must only say that it indicates partially decomposed organic matter.

Rep. Mass. S. B. H. Water Supplies 1887-1890 p. 550.
" " " 1892 p. 319 et seq.

The albuminoid ammonia measures the amount of undecomposed organic matter, or more exactly the amount of nitrogen in it.

The nitrates indicate completed decomposition, and are harmless in the quantities usually occurring.

The fixed residue measures the mineral constituents and the loss on ignition is an indication of the volatile constituents.

The quantity of oxygen consumed bears some relation to the amount of carbon present, but different substances behave very differently with the permanganate of potash, and hence this factor is only useful in comparing similar waters and has no significance with waters of dissimilar origin and nature.

Rep Mass. S. B. H. 1892 p. 328.

So far as micro-organisms are concerned they are only indicated in the chemical analysis by a slight increase in the albuminoid ammonia which can in no way be separated from that due to partially decayed or dead matter. One of the best evidences of this is given by Prof. Frankland (Micro-organisms

in Water p. 101-102), in an account of an examination of the River Dee in Scotland, which supplies Aberdeen with its water. The examination covered forty miles of river and beginning at the source the number of bacteria per cubic centimeter was first only 88, at the next point of observation they had increased to 2,829, at the next they had decreased to 1,139, then they increased again to 3,780, decreased to 938, increased to 1,860 and finally decreased to 950, and yet through all these changes in which the increases were uniformly caused by added sewage, Frankland says, "It was found impossible by means of chemical analysis to detect any material alteration in the composition of the river, even immediately below each of the above sources of contamination."

The fact that chemical analysis does not indicate changes in the bacterial compositions of either sewage or water is shown by the following examples of analyses, taken at random from the Report of the Massachusetts State Board of Health for 1891, and covering a wide range of conditions.

PARTS PER 100,000.

	Free Ammonia.	Albuminoid Ammonia.			Chl'rine	Nitrogen as		Oxygen Consumed.	Bacteria Per C.C.
		Total.	Soluble	Insoluble.		Nitrates	Nitrites		
Lawrence Sewage. Average of daily Analyses for									
1888	1.5528	.6878	.1161	.5267	5.19	0	0	--------	1,000,000
1889	1.8439	.5540	.2909	.2631	4.92	0	0	--------	708,000
1890	1.8200	.6862	.3805	.3057	5.45	0	0	3.25	1,085,000
1891	2.2196	.7295	.3446	.3849	7.37	0	0	3.64	693,000
Analysis of									
July 3, 1890	2.50	.65	.51	.14	4.87	—	—	2.90	7,560,000
" 7, "	2.10	.81	.57	.24	7.07	—	—	3.30	807,000
" 14, "	2.75	.88	.88	.00	5.97	—	—	3.00	159,060
" 17, "	2.75	1.05	.55	.50	6.10	—	—	2.80	1,401,000
Effluents of Sewage Filters.									
Analysis of									
Oct. 2, 1891	.0242	.0144	—	—	10.46	3.06	.0018	.15	3,600
" 9, "	.0132	.0128	—	—	8.16	3.20	.0014	.14	50
" 16, "	.0012	.0144	—	—	8.02	1.67	.0080	.16	19,440
" 23, "	.0070	.0104	—	—	6.86	1.85	.0004	.18	138
" 30, "	.0102	.0096	—	—	7.10	1.66	.0012	.10	280
May 8, 1890 9:15 a.m.	.8000	.0500	—	—	4.39	2.75	.0200	.12	1,836
" " " 11:08 "	.8200	.0800	—	—	4.39	3.00	.0140	.13	1,404
" " " 2:42 p.m.	.8000	.0800	—	—	4.34	2.75	.0120	.14	6,318
" " " 5:24 "	.8500	.0500	—	—	4.36	3.00	.0180	.11	12,204
" " " 8:45 "	.8500	.0500	—	—	4.39	2.75	.0220	.12	1,026
Lawrence City Water. Analysis of									
Dec. 9, 1891	.0028	.0138	—	—	.25	.0260	.0002	.40	38
" 16, "	.0034	.0148	—	—	.21	.0330	.0002	.41	330
" 23, "	.0030	.0136	—	—	.24	.0320	.0002	.39	1,320
" 30, "	.0030	.0120	—	—	.22	.0200	.0001	.37	156

Prof. Drown discussing this subject, says: (Rep. Mass. S. B. H. Water Supply, etc., 1887-1890, p. 536). "Students of sanitary science have attempted to establish certain standards of purity of water based on the determination of nitrogen. These standards express limits for organic nitrogen, or albuminoid ammonia, free ammonia, nitrites and nitrates, beyond which the water containing them should not be used for drinking. Some of them have the sanction of sanitary congresses, and some are merely the expression of individual opinion. The application of these standards of purity has condemned many waters which were certainly unfit to drink, but it is equally certain that many wholesome waters have been thereby rejected. The following table from another part of the same report (p. 541) brings out this point:

Parts per 100,000.		Color.	Residue on Evap.			Ammonia.		Chlorine.	Nitrogen as	
			Total.	Loss Ig.	Fixed.	Free.	Alb'm'd.		Nitrates	Nitrites
Unpolluted Waters.	No. 1	0.00	5.00	0.70	4.30	.0000	.0022	0.08	.0060	.0000
	2	0.10	2.50	0.95	1.55	.0000	.0702	0.10	.0030	.0006
	3	0.60	5.15	3.25	1.90	.0000	.1252	0.11	.0000	.0000
	4	0.40	3.65	1.65	2.00	.0130	.0333	0.16	.0250	.0001
	5	0.30	3.25	0.95	2.30	.0000	.0136	0.63	.0050	.0000
	6	0.00	5.95	0.80	5.15	.0000	.0152	2.10	.0060	.0001
Polluted Waters.	7	0.10	10.75	2.05	8.70	.0124	.0284	0 19	.0150	.0009
	8	0.55	5.15	1.95	3.20	.0000	.0196	0.54	.0550	.0004
	9	0.10	5.00	0.85	4.15	.0016	.0198	0.58	.0200	.0004
	10	0.15	10.25	1.20	9.05	.0000	.0262	2.09	.0170	.0010
	11	0.15	12.70	2.10	10.60	.0664	.0263	2.41	.0800	.0025

"The fallacy of making 'standards of purity,'" continues Prof. Drown, "based upon the organic nitrogen, ammonia, nitrites and nitrates, is apparent when we consider that these substances are not injurious in themselves, at least to the extent which they are found in natural waters, and that the presence of any one of these substances in water does not in itself necessarily carry with it any indication of its origin. These standards are relics of the days in which the harmfulness of a water was supposed to be the direct result of the injurious action of specific substances found in it. The theory of today is that it is (in the large majority of cases) to the presence of micro-organisms in water that its harmful influence is due."

Thus the chemical analysis is seen to be often insufficient to determine previous sewage pollution in water, and in the

case of surface water it is often superfluous. As has been very pertinently remarked, "It does not need a chemical examination to decide whether a stream is polluted or not when one can see the sewage flowing into it."

If chemical analysis is not a reliable guide as to the quality of a water supply, it may very properly be inquired, "What is?" To this I would reply that every source of information bearing upon the waters should be investigated. The engineer should be called upon to ascertain all possible or probable sources of pollution, and the source of the water itself. This information should be given to the chemist who should then make his examination. The idea often prevalent in some communities that the way to get a fair result from an analysis is to keep the chemist in entire ignorance of the source of the water and everything about it, is most erroneous. While chemistry is an exact science and there is not likely to be much doubt as to the constituents found, the interpretation of results depends for its correctness on all the facts concerning the water being properly considered. Next the microscopist should be called upon to determine the organisms, vegetable and animal, that are recognizable with his instruments. These organisms may not be positively harmful but frequently give to the water disagreeable tastes and odors, so that their presence is not to be desired. Finally the services of the biologist should be invoked to determine the number and kind of bacteria present. It is only since 1882 that a method of accurate determination of bacteria has been known. This method consists in the forming of a so-called "culture" upon gelatine enriched with peptone or other substance in which the bacteria thrive by inoculating with a portion of the water to be examined, when each bacillus becomes a colony of hundreds or thousands, which clinging together can be readily counted by the aid of the microscope, and their peculiarities determined. The ordinary unit selected for microscopic and bacterial determinations is the cubic centimeter which is about the size of the ordinary player's die, the old nickle five cent piece being very nearly two centimeters in diameter. As an example of the number of bacteria present oftentimes, Lawrence sewage dur-

ing October, 1893, averaged 1,125,000 per cubic centimeter, and the lowest monthly average was that of September, which was 626,000.

The number per gram (about one-thirtieth of an ounce, Troy) in the faeces of a healthy man ranges from as low as 10,000,000 to 200,000,000, while those of typhoid fever patients contain as high as 1,000,000,000. "If we assume that a man discharges about seven ounces of faeces daily, this would give for typhoid patients 200,000,000,000 bacteria discharged daily per person" (Filtration of Public Water Supplies, p. 133). The number of bacteria found in sewage is usually higher, often double this number per person. Not all, fortunately, of these bacteria are dangerous, perhaps ordinarily not more than one in two or three thousand, but the faeces of typhoid patients contain the germs of that disease, and although in water there is no evidence that they, or any other disease germs increase, they retain their vitality for varying periods, and if granted favorable conditions will at once develop colonies of fellows. It is the possible presence of these latter organisms that renders chemical analysis fruitless for the purpose it has been so long considered final.

Now as to the self-purification of rivers, it takes place to varying extents in three ways. By dilution, by sedimentation, and by oxidation and light.

The first means is by far the most important. The inflow of pure or unpolluted water below the point of contamination reduces the percentage of dangerous organisms in the stream. This inflow of purer water comes not only from visible tributaries, but from subterranean streams flowing into the river at all points, so that while there may be no visible tributaries an immense increase may take place in the flow of the stream.

The second means of purification, subsidence, is due to the fact that the mineral matters and about half of the organic matter are merely in suspension and if the current be not too swift, these will settle by gravity to the bottom and may carry with them a considerable number of bacteria. On this account partially more bacteria are found in the lower than in the upper layers of a body of water. So a stream that has flowed

through a lake or pond or reservoir, may be expected to contain a smaller number of bacteria than it did before entering the same.

The effect of oxidation, supposedly promoted by aeration in the passage over falls and through rapids, is greatly overestimated. Examinations of Niagara River water above and below the falls showed practically the same bacterial composition. The experiments of the Massachusetts Board of Health (Report for 1892, p. 320), prove that oxidation of the organic matter from ammonia to nitrates only occurs in the presence and by the aid of certain bacteria, but the completion of the process is no evidence of the termination of life of any of these or other organisms. Moreover, the time required for oxidation of these organic matters in solution differs widely under different circumstances and the vegetable growths in the channel frequently mask the action of the process by appropriating its products at various stages (Mass. S. B. H. Rep. 1890–Pt. I, p. 575). Besides all this, the period of life of some bacteria has been studied, and among them, that of the typhoid bacillus has been found to be from fifteen to thirty days in Merrimac River water, and somewhat longer in the purer effluents of some of the filters, and these bacteria do not appear to be affected by oxidation, and some European experiments show that they are not affected by sunlight at a depth of nine feet in water. (Mass. S. B. H. Rep. 1892 p. 528). (Micro-organisms in Water, p. 372). How far would these bacilli travel in an ordinary river during a life time of fifteen days? I venture to say considerably more than twenty miles. Indeed we have the best of evidence that after traveling thirty-nine miles from Lowell down the Merrimac River through almost stagnant mill ponds and over dams and through rapids, the last fourteen miles of the journey being affected by tide water, they still had sufficient vitality to pass through pumps and water pipes and produce an epidemic of typhoid at Newburyport, in January, 1893 (Mass. S. B. H. Rep. 1892, p. 701), and the repeated epidemics of typhoid at Lawrence following those at Lowell nine miles up the river, give conclusive evidence of their vitality through similar vicis-

situdes for the shorter distance, although the water was stored for more than a week in the Lawrence reservoir, while some of the epidemics at Lowell appear to have been caused by the disease as far away as Concord, N. H., forty-eight miles up the river. Nor is an epidemic necessary to produce these results. Four cases of typhoid three miles above the intake of the Lowell water works in 1890 caused an epidemic in that city involving 550 cases and resulting in 92 deaths, which was immediately followed by one almost as severe in Lawrence (Rep. Mass. S. B. H. 1892, p. 668 et seq.). But it is not necessary to go to Massachusetts for evidences of the vitality of pathogenic bacteria. In the report of the Michigan State Board of Health for 1891 (p. 217) Prof. Vaughan gives analyses and experiments with samples of water from the Detroit River taken at Wyandotte, proving the water there to be contaminated by Detroit sewage and containing germs that were deadly to the lower animals and probably disease breeding in men.

The principal methods in use for the purification of water are sedimentation, bleaching, chemical precipitation, and filtration. The first is accomplished by bringing the water to rest for a comparatively limited time in shallow basins when the suspended matters fall to the bottom and the clarified liquid is drawn off from above. Bleaching is accomplished by storing the water for long periods in deep reservoirs by which means the color and many other disagreeable properties are removed and any dangerous bacteria are left to die a natural death. Chemical precipitation is accomplished by treating the water in tanks with chemicals which cause a deposit of both suspended and dissolved matters. But by far the most important method of purification is filtration.

The necessities of filtration are not nearly so well appreciated in America as in Europe. In Germany the law requires that every surface water used for a public supply shall be filtered, and minute regulations are enforced regarding the operation of each filter, including among other requirements a daily biological analysis of the effluents by a person of assured capability to conduct the investigations. In England, filtration of surface waters, though not universal, is extensive, and is almost

universal in Belgium and Holland and quite common in France. It is the opinion of some that filtration is only a straining process and hence removes only the substances in suspension. The error of this view will appear as we proceed with the consideration of our subject, but we will first glance briefly at the history of filtration, for which I am chiefly indebted to the paper by Mr. Moore.

The first sand filter was constructed at London in 1839 by Mr. James Simpson, engineer for the Chelsea Water Co. "This consisted essentially of a shallow reservoir with a collecting drain through the center and with lateral drains of porous tiles or bricks without mortar leading into the central drain. On top of this system of drains were laid from three to four feet of gravel and sand decreasing in fineness to the top. Through this sand bed water was allowed to percolate slowly into the collecting drains, whence it was led off to the wells for distribution." So successful was this device in removing sediment and improving the appearance of the water that in 1852 its use was made compulsory with all companies supplying London with surface water, and the filter was rapidly adopted elsewhere, both in England and on the continent. The earliest attention given to the subject in America appears to have been in 1866, when the St. Louis Water Board, then having under consideration the construction of new works, sent their engineer, Mr. James P. Kirkwood, to Europe to investigate and report on the subject of filtration. Though his recommendations regarding the St. Louis works, after being endorsed by the Water Board were rejected by the City Council, the report was published in 1869 and is even today considered almost a classic on the subject. So complete was it in description and so clear and ample in its suggestions and deductions that notwithstanding the improvements and developments of the process, it has remained until within a year the only treatise on filtration in the English language. At the time of his visit he found filtration plants in operation in Berlin, Altona, Nantes and Marseilles on the continent, and in Leicester, York, Liverpool, Edinburgh and Dublin as well as in London.

While the theory lasted that the harm in polluted waters lay in dead matters in suspension, this method of purification left nothing to be desired as by it turbid waters were rendered clear and as far as the eye could judge pure. But when in the course of time scientific investigation developed that the danger did not lie in the dead matter at all, but in minute living organisms, engineers, sanitarians and medical men alike stood aghast. The cost of obtaining natural water from unpolluted sources put it beyond the reach of many towns, and the preservation of streams unpolluted flowing through a densely populated territory was seen to be alike impossible. When it was discovered that the clearest and most sparkling of waters might be the most deadly, the benefits of filtration were regarded as chimerical. The sentiment at this time is well voiced in a paper by Mr. Charles Watson Folkard, associate of the Royal School of Mines of England, read before the Institution of Civil Engineers in January, 1882, which is quoted by Mr. Moore. After he had discussed the various methods of water analysis, he said: (Proc. Inst. Civil Engineers, Vol. 68, p.68) The conclusion that once contaminated, water never purifies itself sufficiently for dietetic purposes becomes inevitable; and as chemical analysis fails to give reliable evidence as to its fitness or the reverse, the author believes that the only safe test of the wholesomeness of a given water is by tracing it to its source and ascertaining that no objectionable impurities gain access to it. This will at once condemn all rivers flowing through a populous country; and when it is considered that a river is a natural drain of a district, into which everything soluble or suspensible finds its way, it will not be a matter of wonder that this is the case. No Conservancy Board can keep pollution out of a river; it must receive all the rain falling within its water shed (excepting of course that which is evaporated) together with the overflowings of cess-pools and the sewage of towns within the same area. It is part of the great circulatory system of the earth, which it is vain for man to attempt to control. This being so, it is evident that rivers, excepting near their source can only afford polluted water, and a problem utterly insoluble by man, is presented, viz., the purification of

foul water on a large scale." Continuing with regard to filtration, "This," he says, "is another remedy put forward as infallible by those who have not grasped the subject. How can filtration affect substances dissolved in water? And as far as the minute organisms found in putrescent bodies are concerned, they could pass a hundred or a thousand abreast through the interstitial spaces of ordinary sand as used for this purpose."

This paper was discussed by a number of very able men, among them the late Professor Tyndall and the preponderance of opinion was with the author. Mr. Homersham declared that in some respects and at some seasons filtration really injured the water by the collection of a layer of organic matter on top of the sand which furnished pabulum for the insects as he termed them, and Dr. Tidy said "One could no more analyze a water for a germ of typhoid than one could analyze a brain for an idea."

But right on top of these declarations, the very same year 1882, Dr. Robert Koch of Berlin, gave to the public the gelatine plate process of determining micro-organisms already described, which at once advanced bacteriology to the degree of an exact science. Among the many students who immediately seized upon this newly discovered agent of investigation, was Percy Farraday Frankland, Professor of Chemistry in University College, Dundee. He at once began an investigation of the work of the London filters, which has continued to the present time. His conclusions were first set forth in a paper before the Institution of Civil Engineers, in April, 1886, and later in reports to the Royal Commission on Metropolitan Water supply, then considering the supply of London, which were published by the Commission in 1893. In brief, Professor Frankland's conclusions were: That the London filters had practically no effect on the chemical composition of the water. That they had a most remarkable efficiency in removing bacteria, about 99½ per cent. of those in the raw water being removed; and finally, that this extraordinary biological efficiency depends upon the formation of a superficial gelatinous deposit or membrane on the top of the sand which acts as an almost impervious obstacle to the passage of micro-organisms.

Here was a revolution. As Mr. Moore very aptly says: "Mr. Folkard's army of microbes marching 'a hundred or a thousand abreast through the interstitial spaces' has somehow been put to rout and the cause of their discomfiture is found in the superficial layer of organic matter which according to Mr. Homersham should furnish the "insects" with "pabulum," all of which illustrates anew the extreme danger of *'a priori'* reasoning in matters of physical science."

The third conclusion of Professor Frankland, though supported by most European authorities, is not borne out by the experiments of the Massachusetts Board of Health. This subject is discussed by Mr. Hazen in "Filtration of Public Water Supplies" (p. 80 et seq.) as follows: "It was observed in Berlin and Zurich that the bacteria in the effluents were quite independent of those in the raw water and the conclusion followed that the filter stopped all of the latter and that the former were bred in the underdrains. It was, however, noticed that immediately after scraping (i. e. removing the sediment layer) for two or three days the bacteria in the effluents increased and it was concluded that before the formation of the sediment layer some bacteria were able to pass through the sand, and it was recommended that the first water filtered after scraping be rejected. Piefke at Berlin gave the subject careful study, and came to the conclusion that it was almost entirely the sediment layer which stopped the bacteria, and that the bacteria themselves in the sediment layer formed a slimy mass which completely intercepted those of the passing water. When the layer was removed by scraping, the action was stopped until a new crop had accumulated. In support of this idea he stated that he had taken ordinary good filter sand and killed the bacteria in it by heating it, and that on passing water through, no purification was effected—in fact, the effluent contained more bacteria than the raw water. After a little, bacteria established themselves in the sand and then the usual purification was obtained. Piefke concluded that the action of the filter was a biological one; that simple straining was quite inadequate to produce the results obtained; that the action of the filter was mainly confined to the sediment layer, and that the depth of

sand beyond the slight depth necessary to support this layer had no appreciable influence on the results.

The effect of this theory is to be still seen in the shallow sand layers used at Berlin and some other German works, although at London the tendency is to thicker layers. Piefke's deductions, however, are not entirely supported by his data as we understand them in the light of more recent investigation. The experiment with sterilized sand has been repeatedly tried at the Lawrence Experiment Station with results which quite agree with Piefke's, but it has also been found that the high numbers, often many times as high as in the raw water, do not represent bacteria which pass in the ordinary course of filtration, but instead enormous growths of bacteria within the sand supported by the cooked organic matter in it. It has been repeatedly found that ordinary sand quite incapable of supporting bacterial growths, being heated to a temperature sufficient to kill the bacteria in it, will afterwards furnish food for extraordinary numbers. A filter of such sand may stop the bacteria of the passing water quite as effectually as any other filter, but if so, the fact cannot be determined without recourse to special methods, on account of the enormous numbers of bacteria in the sand, a small part of which are carried forward by the passing water and completely mask the normal action of the filter. The theory that all or practically all of the bacteria are intercepted by the sediment layer, and that those in the effluent are the result of growths in the sand or underdrains, received two hard blows in 1889 and 1891, when mild epidemics of typhoid fever followed unusually high numbers of bacteria in the effluents at Altona and at Stralau in Berlin, with good evidence in each case that the fever was directly due to the water. Both of these cases came during extremely cold weather with open filters and under conditions which are now recognized as extremely unfavorable for good filtration. As a result of the first of these epidemics a series of experiments were made at Stralau by Frankel and Piefke in 1890. Small filters were constructed and water passed exactly as in the ordinary filters. Bacteria of special kinds not existing in the raw water or effluents were then applied, and the presence

of a very small fraction of them in the effluents demonstrated beyond a doubt that they had passed through the filters under the ordinary conditions of filtration. These experiments were afterward repeated by Piefke alone under somewhat different conditions with similar results. The numbers of bacteria passing although large enough to establish the point that some do pass, were nevertheless in general but a small fraction of one per cent. of the many thousands applied. The subject has more recently been studied in much detail at the Lawrence Experimental Station, and it now appears that the bacteria in the effluent of a filter are from two sources, directly from the filtered water and from the lower layers of the filter and underdrains. In general the bacteria from the latter source are low in cold weather, often almost *nil* while at Lawrence with water at temperatures varying from 70 to 75 degrees, in July and August, the numbers from this source may reach 200 or 300, but for the other ten months of the year rarely exceed 50 per cubic centimeter under normal conditions. In summer especially the latter seem to be greater in number at a low than at at high rate of filtration while the number of those passing through the filter increases with the rate of filtration. Therefore the increase of one may in part balance the decrease in the other and so keep the total at very nearly a constant figure for quite varying rates of filtration. The bacteria of the underdrains are harmless and are of no interest to us except as they mask the true action of the filter, but those coming through the filter are likely to be dangerous and increase rapidly with the increasing rate of filtration and slowly with decreasing thickness and increasing size of sand grain."

In connection with the investigations regarding water purification carried on by the Massachusetts Board of Health, experiments were also made on the purification of sewage. Two systems of filtration were tried, the continuous and the intermittent. In the former, as the name implies, the liquid to be filtered is fed continuously to the filter until its clogging requires that it be cleansed, while in the latter the inflow is stopped and turned on again periodically. For the purification of sewage owing to the large amount of matter to be disposed

of, it was soon discovered that continuous filtration was unsatisfactory, but intermittent filtration gave very good results. Strange as it may seem, it was further discovered that intermittent filtration through a bed of gravel the size of peas, gave nearly as good effluents as those obtained by passage through an equal depth of fine sands, and contrary to Frankland's determinations in the case of the London filters, it was found that marked chemical changes took place during the flow of the liquid through the filter, ammonia and nitrites being oxidized to nitrates by the aid of the bacteria which lodged in the filter, forming films over its grains while at each emptying and filling the interstitial spaces were filled with air which furnished the oxygen for the process. The results of filtration of sewage through a filter of gravel stones that would not pass a sieve of ⅛ inch mesh but would pass one of ⅜ inch mesh, where working at a rate of 80,000 gallons per acre per day for six days in the week, the sewage being applied intermittently during nine hours of the day, show that 93 per cent. of the organic matter was removed at this rate and an effluent afforded that was "colorless, generally clear with slight turbidity, and with slight odor." As to the bacterial efficiency under these conditions, 99 per cent. of those in the applied sewage were removed. The gravel was 5′ 5″ deep. At slower rates 40,000 gallons per acre per day, 97 per cent. of the organic matter was removed and about the same percentage of bacteria as in the former case (Rep. Mass. S. B. H. 1890, Pt. II, p. 565). These observations and those on a filter of stones from ¾ inch to 1¼ inch diameter giving similar results prove that the action of the filter is to no essential degree mechanical. That it is not a straining through fine pores. "In fact, the passing of sewage through filter paper in the laboratory, which has pores so fine that the process has been regarded as removing from a liquid all matter not in solution, removes from our sewage but 11 per cent. of the sum of the ammonias and about 80 per cent. of the bacteria, while the slow moving of the sewage in thin films over and between stones as large as one's thumb causes the removal for months at a time of 97 per cent. of the sum of the ammonias and 99 per cent. of the bacteria. The removal

is not a mechanical one of holding back these substances, but a chemical change, in which these organic substances are burned, forming products of mineral matter which pass off daily in the purified liquid." (Allen Hazen in Rep. Mass. S. B. H. 1890 Pt. II, p. 567).

The action of the various layers of the filter in removing organic matter and bacteria is shown by the following analysis of sand at various depths from a continuous filter passing Merrimac River Water at a rate of 5,000,000 gallons per acre daily. (Report of Mass. State Board of Health 1894, p. 603).

Depth From Surface.	Organic Nitrogen. (Parts Per 100,000 Per Weight of Dry Sand).	Bacteria Per Gram.
0¼ inch	21.8	5,460,000
1 "	13.3	1,500,000
3 "	6.9	820,000
6 "	4.1	245,000
12 "	4.1	120,000
24 "	1.8	49,000
36 "	1.0	42,000
48 "	0.6	35,000
60 "	1.3	13,500

It was the writer's privilege to visit the Lawrence Experiment station in September, 1895 and I there saw sewage from the main sewer of the city of Lawrence, a city of over 40,000 inhabitants, being passed through about five feet of pea gravel at a rate of a quarter of a million gallons per acre per day, an effluent being obtained of sufficient purity to offer no offense if turned into a stream whose waters were used for any but drinking and culinary purposes, saw this effluent then passed through about five feet of sand very similar to our lake sand at a rate of two and one-half million gallons per acre per day and saw the final effluent of such purity that the assistants in the laboratory had no hesitation in drinking it, its composition being about that of the best spring water.

Owing to the wonderful success of intermittent filtration in the purification of sewage it was applied to the filtration of water and for extremely impure waters will remain probably the best method of treatment. The first filter constructed to work intermittently was that at Lawrence, designed by Hiram F. Mills, C. E., from the experiments of the Massachusetts Board of Health, although at Chemnitz, Germany, the principle of intermittent filtration had been utilized in connec-

tion with a well supply. Mr. Mills describes the Lawrence filter and the reasons leading to its construction in the Report of the Massachusetts State Board of Health for 1893 (p. 545 et seq.) from which is abstracted the following:

"The Lawrence pumping station is by the side of the Merrimac River, from which the supply is taken, above the city and about 1,000 feet up stream from the nearest house. The works have been in use about seventeen years. For some years after they were built—while a filter gallery parallel to the river of small capacity supplied the town—there was a diminuation in the number of deaths by typhoid fever from the number when well water was used, and no one thought of direct poisoning by sewage of the water taken from the river nine miles below Lowell with a fall of ten feet through a rapid a mile long on the way. Many made the remark that running water purified itself in a less distance and put away any fear of contamination, while a few did not relish drinking water into which the sewage of 70,000 people had been poured only eight hours before it reached the intake of the water works. However, in 1890 a careful study of the deaths from typhoid fever in the cities of the state showed that the cities of Lowell and Lawrence had nearly three times the average number as the same population in other cities; and that during the season—August, September and October—when other cities had the most typhoid fever, Lowell and Lawrence had about the same number of cases as other cities, but a month or more later the deaths in Lowell reached three and four and eight times the deaths in other cities, and after another month those of Lawrence increased in a still greater ratio, so that in some years the deaths in January and February from this disease were more than the actual number in Boston, with ten times the population. This condition, following year after year, made it so evident that the disease came down the river to Lowell from the towns above, and then came with greater intensity from Lowell to Lawrence, that the State Board of Health made strenuous efforts to produce a filter that would remove all disease producing germs that could be applied to it, and at the same time

filter rapidly enough to serve for a city's water supply. Billions of typhoid-fever germs were cultivated and applied to filters of different construction, and in 1891 we succeeded in removing all that were applied when filtering 2,000,000 gallons per acre daily."

Then the Board advised the city of Lawrence to filter its water and offered to show how this could be done. Such a filter would require some layers of quite fine sand, and it was thought necessary to first take out the very fine river silt from the water by means of a coarser sand filter at the river bank. Further experiments showed that the construction of a filter at the river bank with a sand coarse enough to allow the river silt to be deposited upon it, if the silt were removed promptly, would serve to remove ninety-eight per cent. of all bacteria of the river water and a still larger per cent. of the disease producing germs; and considerations of economy and the immense advantage of such a filter, with the probability of this or none, with an unbelieving public, induced the State Board of Health to advise the city to immediately construct such a filter and save the fifty-seven lives which was the annual excess of deaths by this disease over the same number of inhabitants of cities of the state having a good water supply.

The top of the filtering sand was to be two feet below low water in the river, and could by a proper inlet be flooded to a depth of about two feet, thus forming a shallow pond of about two and a half acres in extent, which would gradually filter downward to the underdrains and be carried off to the pump well. One of the essentials of the design required that the inlet should be closed once a day and the water pumped out of the sand to allow it to fill with air. This condition of filling the sand daily with air was regarded necessary to insure burning up to nitrates the organic matter which penetrated the sand below the surface, thus producing conditions the most unfavorable for the continuation of the life of bacteria within the water in its passage through the sand and after leaving the filter. The underdrains were placed thirty feet apart consisting of glazed sewer pipe for about 0.4 of the way across and layers of different sized stones for the rest. The supply con-

duit was made of cobble paving stones four to six inches through, laid in Portland cement mortar on a layer of gravel and sand. The sand was deposited in ridges and valleys, the former being over the underdrains while in the latter the carriers were brought out from the supply conduit. These were built of rubble in Portland cement mortar on the sand and were made smooth inside. The sand varies from three feet in depth in the valleys to six feet in depth in the ridges.

The filter when completed required about ten days to get to working properly, but since that time marked chemical changes in the oxidation of albuminoid ammonia to nitrates and the reduction of color in the water have been noted, while 98.3 per cent. of bacteria in the river water have been removed, and by the oxidation of the organic matter depriving them of the means of existence a further reduction takes place so that at the tap in the city hall but 0.9 of one per cent. are found. The experiments of the State Board of Health go to show that with this result we can rely on the complete extinction of all of the disease producing germs that may have been in the water.

As to the results obtained from the filter, up to the period of its completion from 1872, the number of deaths from typhoid fever in Lawrence per 100,000 had exceeded that of any of our larger cities, even Chicago and Philadelphia falling considerably below. Every year as sure as the typhoid epidemic struck Lowell, so sure was it followed by a more disastrous one in Lawrence. During the eight months from October to May inclusive, from 1888 to 1893, the average number of deaths from typhoid were by months as shown in the following table, as is also the record of the same months since:

Months	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Total.
Ave. deaths per month for 5 years without filter	4.0	5.0	8.0	7.0	8.0	6.0	3.5	1.5	43.0
Actual deaths per month with filter 1893 and 1894	1.0	1.0	2.0	2.0	5.0	4.0	0.0	2.0	17.0
Of the deaths in 1893 and 1894 it was found on investigation that unfiltered water in the factories had been drunk by the following numbers	0.0	1.0	0.0	1.0	4.0	3.0	0.0	0.0	9.0
Leaving the deaths among those using filtered water	1.0	0.0	2.0	1.0	1.0	1.0	0.0	2.0	8.0

The filter appears, therefore, to have reduced the number of deaths from typhoid for the eight months from 43 to 8 or over 80 per cent. and through the courtesy of Mr. Wm. R. Copeland, Biologist of the Experiment Station, I learn that the total deaths for the whole of 1895 was only 16, of which 9 had been users of unfiltered water.

A further evidence of the efficiency of filtration in preventing disease is given by the experience of the German cities, Hamburg and Altona during the cholera epidemic of 1892, which is described by Prof. Frankland, (Micro-organisms in water p. 152 et. seq.) as follows:

"These two cities both are dependent upon the river Elbe for their water supply, but whereas in the case of Hamburg, the intake is situated *above* the city, the supply for Altona is abstracted below Hamburg *after it has received the sewage of a population close upon* 800,000 persons. The Hamburg water was, therefore, to start with, relatively pure when compared with that destined for Altona. But what was the fate of the two towns as regards cholera? Situated side by side, absolutely contiguous in fact, with nothing in their surroundings or in the nature of their population to especially distinguish them, in the one cholera swept away thousands, whilst in the other the scourge was scarcely felt; in Hamburg the deaths amounted to 1,250 per 100,000 and in Altona to but 221 per 100,000 of population. So clearly defined, moreover, was the path pursued by the cholera, that although it pushed from the Hamburg side right up to the boundary line between the two cities, it there stopped, this being so striking that in one street, which for some distance marks the division between these towns, the Hamburg side was stricken down with cholera, whilst that belonging to Altona remained free. The remarkable fact was brought to light that, in those houses supplied with Hamburg water, cholera was rampant, whilst in those on the Altona side and furnished with Altona water not one case occurred. The Hamburg water, however, to start with was, as we have seen relatively pure when compared with the foul liquid abstracted from the Elbe by Altona; but, whereas, in the one case the water was submitted to exhaustive and careful filtration

through sand before delivery, in Hamburg the Elbe water was distributed in its raw condition as taken from the river. But further testimony was afforded later to the truth of this interpretation; for during the ensuing winter, when the cases of cholera had almost completely died out in Hamburg, suddenly a most unexpected and unaccountable recrudescence of the epidemic occurred, and this time in Altona. This outbreak could not be traced to any direct infection with Hamburg, but must have arisen in Altona itself. In all, about forty-seven cases were recorded between Dec. 23, 1892 and Feb. 12, 1893. A searching inquiry was instituted and it was ascertained that the number of bacteria in the filtered water, usually about 50, had, during these months risen to as many as 1,000 and more per cubic centimeter, clearly indicating that the filtration of the water was not being efficiently carried out. That this was actually the case was proved by the fact that one of the sand filters, which had been cleaned during the frost, had become frozen over, and was in consequence not able to retain bacteria. That the outbreak did not become more serious Koch ascribes to the fact that this imperfectly filtered water was so largely diluted by that which had been efficiently filtered."

The first consideration in the construction of sand filters is to so design them that every part of the surface shall filter with the same rapidity. To accomplish this not only the resistence to flow through the sand is to be taken into account but also the friction in the underdrains. For best results it is also desirable to have an impervious bottom to prevent the inflation of ground water which often tends to increase the hardness of the effluent if it does no worse. The ordinary construction is to surround the underdrains with gravel and on top of this to lay the sand from four to five feet deep of uniform size, although some vary the size from fine to coarse downward, while in the Lawrence filter two sizes of sand were used, the coarser being on top, which would probably be an unsatisfactory arrangement in continuous filters. In operating care must be taken that the inflowing water does not disturb the surface of the filter. When the surface layer becomes clogged the water is drawn off and the surface is scraped,

removing the sand from one-quarter to one inch in depth, which is afterwards washed and may be reused. Usually about once a year, in English practice, the filter is renewed by removing and replacing all the sand, but the Lawrence experiments prove that filters are more efficient when undisturbed the fourth year than they were the first. (Report Mass. S. B. H. 1894). The scrapings are required usually from once in ten to thirty days. In European practice after scraping it is customary to waste the effluent of the filter for a few days, as it is found that more bacteria pass during the three days following scraping than at any other time, but the Lawrence experiments indicate that by working the filter for the first three days at a slower rate and by using a good depth of uniform sized sand the danger may be averted without waste. The usual rate of filtration with ordinary waters is two and one-half million gallons per acre per day. The observations of 1894 at Lawrence indicate that old filters may be safely worked at higher rates.

As to the cost of filters, that at Lawrence is one of the cheapest ever constructed, it being two and one-half acres in area in one bed and cost $67,000, or $27,000 per acre, but no effort was made to render the bottom impervious. In climates where freezing weather is of frequent occurrence or of long duration, filters should be covered, as frost interferes greatly with their efficiency, and as water flowing under ice is particularly liable to bear contamination and dangerous bacteria. (Micro-organisms in water, p. 147). The cost of continuous filters uncovered, ranges from $20,000 to $45,000 per acre, and for covered from $40,000 to $90,000. Mr. Hazen estimates for small filters an average cost of operation of $1,500 per annum per million gallons daily, but as a large amount of this is for superintendence, examination and testing, which would not increase at the same ratio as the size of the plant, this figure based on an 8,000,000 gallon plant seems large for a large plant. The Lawrence filter treating on the average 3,000,000 gallons daily cost for operation and maintenance in 1894 about $4,600.00 or a little over $1,500.00 per million, which shows the figure correct in this case.

No discussion of the subject of this paper could be complete without some mention of mechanical filters, which since 1889 have been coming into extensive use and have reached a sufficient degree of perfection to be adopted in such cities as New Orleans and Atlanta, and to be carefully considered in Minneapolis and Providence. These filters may be classed under two heads. Those which use coagulents and those which do not. In the latter class the water is simply passed rapidly through sand in iron cylinders and this sand is frequently washed with the filtered water. The same rules govern here as in slow sand filtration and as it has been found there that bacterial efficiency cannot be obtained at rapid rates of filtration, we have no reason to expect it in the mechanical filter under the same circumstances. We have excellent proof, in the experience of a Vermont town mentioned by Mr. Hazen ("Filtration" p. 107) where an epidemic of typhoid was caused by water previously passed through one of the leading makes of this type of filter, that they are unreliable. When, however, a coagulent is added to the water before passage through the filter, we have an entirely different case to consider. This coagulent, frequently alum, lime or a salt of iron forms a chemical union with the suspended and dissolved matters and precipitates them, by which process the bacteria are also carried down entangled in the sediment, or else the results of the combination remain in suspension in masses of such size as to be easily removed by the passage through the sand, even though at a rapid rate. In some recent experiments in Providence, water was treated at a rate of 128,000,000 gallons per acre daily with a bacterial efficiency of over 98.5 per cent. These filters have gained a considerable foothold from their lower first cost as compared with sand filters, but their use seems to be accompanied with much more risk than is the slower sand filter. The difficulty is that unless the coagulent is added in exactly the proper proportions to dispose of the foreign matters in the water, the excess if any is carried over in the effluent often producing as disagreeable if not as dangerous results as the original pollution, and if an insufficient quantity is used some of the impurities are carried over. As the impurities in water

vary from day to day, and sometimes from hour to hour, to secure the perfect action of such an apparatus requires an amount of judgment and skill rarely found in those who are employed to operate such plants. Moreover, a careless or sleepy attendant may fail to apply the coagulent at the proper time and a million gallons or more may thereby pass through without treatment and no one be the wiser until the health of the consumers bears testimony. In slow sand filtration it is different. If the filter is not properly cared for it ceases to deliver water at the required rate and thereby gives warning of its condition. At the same time the latter is too delicate an aparatus to leave to run itself and requires care and judgment in its operation. We shall, however, await with much interest the results of the Louisville experiments with mechanical filters which are now being carried on under the direction of Mr. George W. Fuller, who followed Mr. Hazen in charge of the Lawrence Experiment Station.

Household filters, unless properly cared for, are more often a source of danger than a protection against it. Mr. Hazen (Filtration, p. 116) says, "Those usually sold as germ proof, consisting of sand, animal charcoal, wirecloth, filter paper, etc., do not afford protection against any unhealthy qualities which there may be in the raw water. Animal charcoal removes color without removing the far more objectionable bacteria." In regard to the efficiency of the better class, Frankland (Micro-organisms in water, p. 172) experimented on a Pasteur-Chamberland Filter and found it, when new, to be bacterially perfect in efficiency, but in filtering filtered Thames water, it decreased its yield rapidly. Freidenreich carried on more extensive experiments with this filter, which as reported by Frankland (p. 174) showed that after six days' operation at a temperature of 35 degrees C. the filtrate contained bacteria. Whether dangerous or pathogenic bacteria can pass through this or similar filters has not as yet been determined, but if even these filters are used, the authorities say they should be frequently sterilized. But it occurs to the writer in view of Mr. Hazen's discoveries of the growth of bacteria in sterilized sand, recorded above, that it might not be impossible for a

similar action to take place under like circumstances in a Pasteur-Chamberland filter, so that frequent sterilizing might not be an unmitigated blessing. This is a point, however, that I have never heard discussed, but I am informed that the Pasteur-Chamberland filters used at the Columbian Exposition were never sterilized.

The President.—Gentlemen, you have this paper of Mr. Williams before you for discussion. I have the 18th and 19th Annual Reports of the Lawrence Water Board which contain some photographs and cuts of plans of those famous filters, and they are being passed around the room now.

Mr. Sears.—I feel personally thankful to Mr. Hazen and Mr. Williams for these interesting papers, or anything that will lead to the diminution of the sewage evil. I was thinking, as they are both good looking gentlemen, that I was sorry they were not talking to our wives and sweethearts, instead of to men. Here in this community—and I want to get out of it for that very reason,—you cannot stir up enthusiasm enough to secure pure water. These papers should be put in pamphlet form and circulated throughout the State so that the women can read them. They will stir the men to action.

Mr. Wells.—It occurs to me that it would be a good idea to incorporate these two papers in the Report of the State Board of Health. I don't believe they have had two such able papers as these.

Mr. Hazen.—Not being a member of your society, I don't know whether I am allowed to speak or not.

The President.—You have the freedom of this Society.

Mr. Hazen.—I was glad to hear what Mr. Williams said in regard to the mechanical filters. I did not take up the discussion of them last night because it is a subject that has not been thoroughly investigated as yet, and we are waiting for more information.

These mechanical filters were originated in the paper mills of New England; I believe the Cumberland mills, just above Portland, Maine, were the first to use them. They were devised to take out the particles from waters which would

injure the texture of the paper, and in doing that they have been eminently successful and have accomplished a great work in that particular field. No one recognizes that more fully than I do. It has been thought by many people that because they were successful in paper mills they would be equally good for filtering town and city supplies; but it needs but little reflection to show that the case is entirely different, and the particles which it is necessary to remove in paper manufacture are entirely different in size and nature from the organisms and properties in water which render it injurious for drinking, and because a filter is satisfactory in one case, we cannot argue that it will be successful in another. It must be judged entirely on its own merits in doing this particular work, and upon this problem there is not sufficient evidence, except that we do know that when alum is not used, satisfactory results cannot be accomplished.

The Providence filters, in regard to which Mr. Williams spoke, are said to have given in some cases a very high efficiency, and in other cases very much lower efficiencies, so that there seems to be some doubt as to whether the high efficiency could be depended upon in all cases. But as the results have not been published, and as we have only seen a part of them through the courtesy of Mr. Weston, the engineer who made the experiments, not much can be said upon the subject.

We shall, as Mr. Williams has said, look with great interest for the results of the experiments now being made at Louisville. It has seemed to us that until this subject is cleared up we could not afford to recommend a process about which so little is definitely known. We cannot as yet call the mechanical filters past their experimental stage.

At New Orleans the city refused to accept such a plant put in by a company, on the ground that the company did not fulfill its contract, and the court sustained the city, and the company is said to be bankrupt. So it was not an unqualified success in that case.

The sand filtration in regard to which we have been speaking is so well understood and has been so widely used that we

can speak of it with the greatest confidence, and can recommend it to the cities needing filtration. The cost of construction may be greater than the cost of mechanical filters, but the cost of operation is probably less. Under the circumstances we have felt that we were only justified in recommending that process to cities, and that we could afford to wait until more was known about the mechanical filters before recommending them.

Mr. Keeler.—I would like to ask Mr. Williams if he has any knowledge of the working of the filter plant at Mt. Clemens. They have a mechanical plant there with a capacity of about one million gallons,—used for domestic purposes and fire protection. They pump right along when there is fire without lack of supply. As to the quality of the water, I talked with some of the commissioners and they are very well pleased with it, but as to the scientific results, I had not learned anything.

Mr. Williams.—We sometimes have to resort in these cases, to analogy. I have no personal knowledge as to the results obtained from the filters at Mt. Clemens, but I do know this, that the people at Mt. Clemens are at present very anxious to get a supply of water from Lake St. Clair, and they have employed Mr. George H. Benzenberg, City Engineer of Milwaukee, to report upon the feasibility of obtaining water from Lake St. Clair, and I presume if they were satisfied with the present system, they would not be looking for a supply at such a distance.

Mr. Keeler.—The reason they are looking to Lake St. Clair is, I believe, because the river is failing. They are afraid they will be shut off on account of the lack of water in the river.

Mr. Wells.—Since we have had the practical application of electricity, people have grown into the habit of thinking they can do business at long range. I do not think this is so in the matter of examining water supplies. The only way to court the acquaintance of the bacteria is to get right on the ground, where they are, and cultivate an acquaintance at close range. The company with which I am connected has had some

experience, which shows to what extent a wrongly conducted examination can be injurious.

On one plant, in which the difficulty with the water supply has been very great, the borough brought suit to have the contract anulled. It was a case in a Court of Equity, and the borough had one of its councilmen take a jug, whose history was unknown, and gather up a sample of the water, and send it to an employee of the State Board of Health. The young man made a chemical analysis of it,—found 503 solids in a million parts, and very readily condemned the water. The truth of the matter was, that there were over 200 parts of those 500, which were salt,—and he also condemned it on account of the sewage contamination I believe. The truth of the matter is that salt is a mineral there, and of course is not injurious to the health. The young man admitted on the stand that his process of reasoning was not regular, but still it had a great deal of weight with the court, and the contract was annulled.

Now if that man had gone on the ground,—had examined the territory from which the supply was taken, he would necessarily have had to make a very different report.

Mr. Williams brought out another point which I find is contrary to common belief,—that you can not sit down in the committee room of a council chamber and write out a standard of purity which shall be an entire protection for the public. I have had to contend with that old idea a good deal and I am surprised at the places where I find it supported by people asking for standards of purity.

In one case, a member of the State Board of Health insisted upon a standard of purity. It was in this same case where the salt was found, and I believe 20 parts salt in 100,000 are allowable, are they not, Mr. Hazen?

Mr. Hazen.—I think the only limit to that is where the salt is tasted.

Mr. Wells.—Some of the old standards of purity put it at 20 parts, I think.

Mr. Hazen.—Oh yes,—the limits placed were often even lower than that.

Mr. Wells.—This physician of whom I speak, was ready to adopt the salt limit of these old reports, which have been widely published—and in a case where the salt was clearly a mineral, it would have thrown out water that was otherwise good.

Mr. Roberts.—In a municipal convention at Cincinnati, last October, Mr. John W. Hill of that city read a paper on pure water, and in the discussion, he made a comparison similar to the papers of Mr. Hazen and Mr. Williams, of German cities, and in the discussion, the question came up as to whether it was really fair to compare the death rate of typhoid fever in American cities with German cities, because so much less water was drunk. He then gave some statistics in regard to beer drinking in American cities. But few would imagine that the total consumption of domestic beer in the United States amounted to 33,000,000 barrels during 1894; it is in the principal cities, however, that the largest consumption occurs, and from imperfect statistics,—although at the present time the best obtainable,—the local consumption is given as follows:

In Boston, gallons per capita per annum	65
In Cincinnati, " " " " "	80
In St. Louis, " " " " "	93
In Milwaukee, " " " " "	105

In Munich, (considered the largest beer drinking German city), the annual per capita consumption is 128.

Mr. Sears.—Where did they have the least typhoid,—where they drank the most beer?

Mr. Roberts.—It appeared so with the German cities.

Mr. Wells.—I wouldn't be surprised if the statistics would show that water had killed more people than beer and whiskey. Frances Willard though, would show the other way probably.

Mr. Appleton.—Very few people have been drowned in beer.

Mr. Rogers.—I have seen it stated in a paper by Col. Waring, that typhoid fever is really a disease of the country rather than cities and towns; take it the country over, and there it is largely traced to the water supply.

Q. You mean the country regions?

Mr. Rogers.—Yes. Country population. I would like to ask Mr. Hazen if that idea is well founded.

Mr. Hazen.—I think as a rule, that country districts and smaller country towns have higher death rates from typhoid fever than most cities, and that is commonly attributed to the use of well water That is a subject which I have not studied in any great detail, as my work has been confined almost entirely to cities.

Mr. June.—In this connection I have noticed that as it has repeatedly been intimated here, typhoid occurs after a drouth, and when there is a dry season, the next winter typhoid fever prevails in the country districts; if there is any further light on that subject,—how the water becomes contaminated—or whether the cold weather is favorable to it,—I would be very glad to know about it.

Mr. Weatherwax.—Can anyone explain the cause of the epidemic in Duluth, where they take their water from Lake Superior, supposed to be the best water in the world?

A. They dump their sewage into Lake Superior just above the city.

Mr. Roberts.—A former resident of Saginaw informed me that the sewage disposal of Duluth was less than a block distant from the water intake.

Mr. Williams—In regard to low ground water and its effect on typhoid fever,—the subject has received some attention; I have had no opportunity to make any original investigations, but the amount of it seems to be this, that where people are dependent on a well for their water, the conditions will ordinarily be observed, that when you have low water,—a drouth,—the water is drawn down low in the wells, and then when the fall rains come on, they will be followed by typhoid; it is possible to explain this on the ground that the substances gathering on the surface, in case of a sudden rain, are washed down into the wells. We have the same thing in the filter. When you start the filter new, it does not retain the germs. Only after it becomes saturated and the bacteria established, does it do good work. So with the ground,—when it is thoroughly dried out, and suddenly treated to a heavy fall of rain,—the great proportion of the substances gathering on the surface, are carried down into the wells.

It is peculiar, as I stated last night, that in the experience in Massachusetts, where well-water supplies are comparatively unused, and the public supplies are mainly drawn from very large reservoirs in which the water remains for a long time before it is used,—or else are taken from deep wells,—that they do not find that this condition exists. Taking the Statistics for fifteen years, they find that the prevalence of typhoid fever has been no greater following long drouths, then following wet seasons, while in the State of Michigan, our State reports bear out closely the theory that typhoid fever is associated with storms following low ground water.

One of the oldest physicians in that part of the State, with an experience covering thirty or forty years, in and about Detroit, said he had learned to look for typhoid to make its appearance after a long drouth, and the more prolonged the drouth, the greater the prevalence of typhoid.

That is not to be taken as an argument against the statement I have made, because Detroit's water supply is not to be compared with the supplies of Massachusetts. Detroit's supply receives, as do the wells, the washings of sudden rains from a drainage area which is tributary to Lake St. Clair and Detroit River, so close to Detroit's intake, that the material washed into these waters and on into the Detroit River, it is entirely possible may pass through our intakes, and though in Detroit, out of a population of nearly 270,000 people I do not think there are three thousand people who are dependent on wells for a water supply, this condition will be found to exist there and will bear out the Michigan statistics, taken from those places where well supplies are used, but will, when studied into thoroughly, corroborate the Massachusetts report.

Mr. Sears.—I think typhoid fever is occasioned greatly by the proximity of the privy vault to the well.

A. It might be so in case of a limited area, as a city lot, but it is rarely the case in the country.

Mr. Hodgman.—There is a question I am interested in. How much protection is sand against the infiltration from privy vaults or from the surface? Mr. Williams spoke of the depth of the water. How much sand ought there to be above

the surface of the water to filter the water before it goes into the well,—if any amount will do this,—how much?

Mr. Williams.—It is a question where to locate that limit. Mr. Hazen perhaps will speak on the subject more authoritatively than I. It has been found, in the operation of filters, that if you filter to-day at a slow rate and to-morrow at a high rate, you destroy the efficiency of filtration. It must take place at a uniform rate. And so the point comes right here: If the filtration from your privy vault is going on at a slow and even rate, through sand,—if your rainfall is evenly distributed, and the sand kept moist, it is perhaps possible that it might be safe with no more sand than we have in the filter bed. It is possible to purify sewage by passing it through five or six feet of sand, but the conditions of the ground are conditions that you cannot control You never know what you are getting, so it is not safe to bring a well in very close proximity with this source of contamination. You would better keep the vault a good distance away.

Mr. Hodgman.—That very question was the source of quite an extended law-suit in my vicinity. It went to the Supreme Court of Michigan and they fought it for all it was worth.

A man purchased a place in proximity to a cemetery—perhaps 25 rods distant. The town proposed to make an addition to the cemetery and he undertook to prevent them from so doing, (he was a physician) on the ground that it would be a damage to his water.

In that case, in the way of testing it, they put into a well, at about that distance, some aniline colors for the purpose of tinting the water and found that it did tint the water in his well, and in that case, the water was from 25 to 30 rods away.

Take it where I live, we have a surface soil of loam from one to six feet in depth, and underneath that is nice, clean sand, clear down to the water. In my own well, the water is 32 feet with probably 26 feet of nice, clean sand on top.

The physician in that instance lost his case, because they said he bought his lot with the cemetery there, and that the addition would not hurt him any.

My property is next to a school property, and they have privy vaults there that go down as far as the sand, and they are at a distance of ten or fifteen rods from my well. The question is, will it affect my well where it must go through 20 feet of sand and then travel that distance?

Mr. Williams.—In all this discussion, there is one point we have lost sight of. In the purification of water, air and the presence of certain organisms are necessary. These organisms have been separated and identified at last, but their habits and the conditions under which they live have not been entirely determined. It is possible they might not be able to live ten or twenty feet below the surface, while they might be able to live in the filter. If I had the case of a well and privy vault within 20 feet of each other, I would not want to drink the well water very much. I would try hard to find something else to drink.

Mr. June.—I have such a case as that, and I have abandoned the well. I think that is the safest way.

Mr. Sears.—I would like very much to hear some comments from my friend, Mr. Webber, on this subject.

Hon. Wm. L. Webber.—I have had no such experience as would justify me in speaking, after the papers that have been presented to this convention.

I will say this, however, while I am on my feet. When the water supply for this side of the river originated at the site of the present water works above here, an attempt was made to filter the water, and filtration was provided by procuring a very fine gravel and sand of various sizes, and quite a field for surface filtration was provided. It operated very nicely until the gathering of sediment spoken of last evening by Mr. Hazen, prevented the water flowing through with sufficient rapidity to supply the works. Then an attempt was made to take off that sediment and wash it, and bring back clean sand in its place, and so change from one layer to another. After an effort of two months in that direction the amount of labor and expense involved proved so great, that the filters were laid aside, and the water was permitted to flow through the pumps without any effort at filtration.

I have been much interested in the remarks concerning the apparent chemical effect of filtration upon water. From what I had learned, I had been led to believe that the poison which produces typhoid fever and diphtheria could not be detected by a chemical or microscopical examination. That about the only way to tell it was for some one to drink it and die, and that was pretty good evidence that it was there.

Now of course we are all familiar with the effect of oxidization on sewage which runs along an open stream. Some of the streams in England, I am told, where there is a large amount of impurity thrown into them, after a flowage of 15 to 20 miles, particularly if they run over a pebbly bottom at a pretty good rate of speed, are considered innocuous, but I learned last evening, for the first time, that the effect of mechanical filtration was to remove the qualities from water which would have rendered it unhealthful.

Of course we know it will take out the mud and leaves, but it won't take out the stain from pine logs; it will take out part of it, so that it does not look quite so dark colored.

Dr. Kedzie, who was once President of the State Board of Health, says that the juice of the pine log is not unhealthful; he does not consider our water any the worse for having the pine logs soaked in it. We had that question under discussion at a convention held at this city, but I will not take up your time further because you have your own things to talk about.

I thank you gentlemen, for your attention.

IRRIGATION ENGINEERING.

BY L. G CARPENTER.

Irrigation engineering in the United States has been a development of the last twenty or twenty-five years. In that time, the conditions of western progress have required the construction of thousands of canals and the expenditure of millions of dollars in order to bring water to apply to lands for agriculture. When confronted with the question there was little to guide the engineer and it has been largely a natural development from experience in the United States. The combined European experience was not accessible to any great extent and it is probable that very few of those who have been instrumental in the development, have known, or had the advantage of the lessons from European practice. Under the conditions, many mistakes, grievous and costly, could not but be expected. They are found on all sides. The wonder is that under the circumstances, more have not been made. The problems to be met with in irrigation engineering are many of them such as require a complete grasp of the laws of the movements of water, and it is true today, as it was centuries ago, that the laws of water are both complex and difficult to understand. The acute Galileo was forced to exclaim in despair that it was far less difficult for him to determine the laws governing the heavenly bodies which were at a great distance than it was to determine those of water which was close at hand. It has been the case in the past that anyone who could run a level has felt competent to lay out a canal, but nothing is farther from the truth. Many canals have been failures in operation because of the unskillful location and the lack of knowledge of the conditions governing a canal and irrigation on the part of the original engineer. When once constructed, a change is costly and requires urgent reasons to modify the location. Nevertheless, many canals have been rebuilt for large distances in order to correct the

mistakes which should have been avoided in the original location. It is true in this as in other engineering, that many faults in construction are not entirely due to the engineer, but to the conditions under which he was forced to work. It is impossible to free him from all blame, though the promoter or the persons who furnish the capital should have a great deal, and in some cases all the blame.

The character of the engineering has been typical of American engineering in general, inasmuch as it has been such as to economize first cost. This leads to greater expense in maintenance, but the necessities of the case have been the same as in other American engineering. The development would not have been possible without a saving of the capital cost and of interest charges. The structures are almost always therefore, of timber, often crude and in reality often very expensive. They are not, in consequence, ones that the engineer will point to with pride. The types have developed under the stress of conditions. The best type of structures to meet the conditions has not yet been agreed upon. A trip over the most successful canals would show structures usually crude and not such as one would usually care to show in a photograph, and those which are frequently shown as examples of irrigation engineering practice, as in the so-called "Engineering results of the United States Irrigation Survey," are mostly structures from enterprises which have been failures. It may be said that the use of temporary structures may be considered as a stage in development. As soon as these enterprises become firmly established and when the communities are willing to pay something to get free from the annoyance caused by poor structures, permanent construction will be adopted in place of the present structures. This is becoming the case already in Colorado as the present structures of wood decay and need to be rebuilt, many are making structures of stone and iron, and more will do so within the next few years.

Notwithstanding the criticisms that may be made upon the engineering, yet as a whole, it may be said to be creditable to the engineers connected with it. While the structures themselves do not compare in solidity, in finish, or in detail, with

those of European and Indian canals, yet it may be said that the European engineers have not been free from serious blunders as well. Water is an exceedingly difficult element to manage, and under the conditions to which it is subject in irrigation, the constantly varying amounts of water, the varying amounts of silt, a great degree of refinement is out of place. But it should certainly be expected that the engineers on such work should at least be acquainted with the elementary laws of hydraulics, and should know enough of the conditions of irrigation to have some conception of the way in which the canals will in future be used.

I have spoken above of canals, but it should not be understood that irrigation engineering is confined to canal work. It involves much more than this and should really include all the questions involved, from the question of water supply and its development to the delivery of the water to the consumers.

One of the first questions to consider in an irrigation enterprise is that of water supply. Priority of right is recognized throughout irrigation states. The first canal which is built has the first right to the water. This may be an absolute or a limited right, sometimes a conditional one. If the enterprise is to take water from a stream already supplying canals, the extent of the rights and the amount of the water remaining after their rights are supplied need to be known. Were this investigated some of the enterprises which have been undertaken would not now be started, to the regret of the stockholders. The water is needed more largely during one or two summer months and to a less extent late and early in the season. With the development of the country, it is probable that means will need to be provided to maintain a nearly constant supply of water throughout the larger part of the season. Where the supplying stream is a varying one, as in most cases, it may need to be supplemented by storage reservoirs or other means of maintaining constant flow. In Colorado a water right which is taken to supply sufficient water for eighty acres is based upon one to 1.44 cubic feet per second, constant flow throughout the irrigation season. This, it may be said, is not too much for about a fortnight at the time of greatest need, while for the rest

of the season it is far more than is needed. This is at the rate of from 55 to 80 acres per cubic foot per second. The net consumption of water is, however, at a much more economical rate, so that actually from 100 to 200 acres may have been irrigated during the season from the constant flow of one cubic foot per second.

Sometimes the statement is made that the duty of water is as high as 400 or more acres. It should be understood that with the same amount of water actually used we may obtain almost any result we please in the duties of water, depending on the time which the water is supposed to run. In all cases, the user does not want the water uniformly distributed, but wants the larger portion of it within a comparatively short time. In consequence if this large figure be taken as a basis for the water rights, some one is bound to be greatly disappointed.

In canal location, topographical features of the country may furnish governing points. Sometimes the canal is to be built to furnish water for a certain tract of land. Its size needs to be determined and the size depends upon the grade. The grade selected should not, properly speaking, be a constant grade, but should vary so as to maintain the same velocity, or else vary so as to change the velocity to correspond to the power of the soil to resist erosion. The velocity desired should also be such as would prevent a deposit of silt in the canal. Experience shows that the velocity can be kept enough to carry the silt through the canal to the land, both to the benefit of the land and the saving of cost of cleaning for the canal. This velocity should be usually from 2 to 5 feet per second. Some times greater velocities are allowable but they should more frequently be below this velocity than above. In most soil the upper limits would be destructive.

The formula used for computing the amount of water carried by canal is that of Ganguillet and Kutter. This is awkward to apply when the formula is used without the aid of tables. It is the best of the formulæ by all means. Its results cannot be implicitly relied upon nor is it probable that any formula can be produced which will not be subject to errors almost as great. The difficulties are inherent in the nature of

the movements of water which cannot be grasped by an equation.

A canal for irrigation has a different function from one for drainage. It is intended to carry water to be distributed over the lands and therefore it seeks the ridges for its location while the drainage ditch seeks the depressions. After leaving the stream, the canal will follow the flanks of the valley and finally may reach the ridge of separation between water courses and may then have to follow this ridge. If the grade is too steep, drops may be required to prevent washing. As compared with a railroad, the latter is flexible vertically but rigid in plan. A canal is flexible horizontally but it cannot vary vertically from the contour line, except in depression.

The canal is usually located in ground with a transverse slope, and it may, therefore, be entirely an excavation or partly an excavation with soil forming the lower bank, or it may be entirely in soil Whether the canal is deep in the ground or not should be regulated by the function of that portion of the canal. If water is to be distributed, then the canal should be shallow so that water can be applied to the surface close to the canal. If this section is used for carriage of water, then it can be placed deep in the ground. Also as the canal passes depressions or points, it may be placed shallow or deep. In the former case the force of the current is away from the artificial bank and in the latter case, the tendency to wash is protected against by the greater depth in the ground. Side slopes are usually made one to one in excavation and one and one-half to one in fill. A berme is not always used but it is an advantage and is well worth using. In the course of a few years' use, the canal washes out in places and the banks become nearly vertical. The berme is a protection to the artificial bank. Some times a sub grade is used and it is an advantage. In this case, the bottom of the canal instead of being level, is made deeper at the center so that with small quantities of water, there is less wetted perimeter, and the location of the current is practically controlled by the cross-section. It is also a question if this idea should not be carried further so as to attempt to control the current at the curves and anticipate the

changes which will take place during the course of a few years' erosion. When a grade of the water surface is determined after the canal is built and filled with water, it is not found to be parallel with the original bottom. Curves and contractions in the cross-section will cause it to vary.

Ravines may be crossed by means of flumes or siphons. The flumes are almost invariably of wood mounted on trestling, much the same as railroad trestling. The same principles of construction would be applied. The flume is intended to carry water and is subject to severe conditions inasmuch as it may be dry for a large part of the year. The alternate wetting and drying is severe on the best of construction and the leaking which may take place is damaging, not only because of the loss of water, but because of the risk to the ends of the structure. The points which need special protection in the case of a flume are the ends connecting with the canal so that the water may be brought into the flume and taken out without washing. Iron flumes will doubtless be used more in the future than in the past. Only two or three have been built in the United States. I have seen them in Algeria and in other foreign countries that have been in use for a number of years. In their case an additional difficulty is to provide for the expansion and contraction of the flume and still preserve a watertight joint. Siphons, by which we mean inverted siphons, are used to a greater extent, and they may in time very largely displace flumes. For small quantities of water and under small heads, I have used ordinary sewer pipe with cement joints. For large heads, wooden stave pipe is being very largely used and has the advantage of cheapness and flexibility and of being constructed in place. Some of these siphons have been built to stand a head of several hundred feet.

The dams in the river or stream may be either a diversion dam or a lifting dam to raise the height of water so that it can be brought to a given level. The conditions for these are evident without description except to say that on sandy streams, the diversion dams are best constructed oblique to the current of the river. In very sandy streams and those subject to

floods, temporary dams of stones and brush are both cheaper and more easily maintained than the more costly ones.

The headgates are among the most important structures on the canals in size and cost. They need to be constructed so as to regulate any amount of water taken into the canal at all stages of the river, to be capable of obtaining a great deal of water at low stages or entirely shut out the water at high stages. The gates need to be capable of management by a minimum number of men and to be certain in operation. As some of the canals are 60 feet broad, and capable of carrying from 7 to 10 feet of water, it is evident that these structures need to be thoroughly made and strong Provisions to dispose of the sand that may enter the canal are necessary in many cases. In some streams sand is very bad and if allowed to enter the canal may cause a very heavy expense for cleaning. Where the canal is favorably located, the sand may be very largely kept out by the construction of a suitable headgate or by provision in the dam or sometimes by the construction of subgrades for the first mile of the canal with suitable waste gates deep below grade which can be used to flush the sand.

Storage reservoirs become an important feature in many of the enterprises. One such dam forms a lake of over 8,000 acres. There are many in Colorado covering from 2 to 800 acres and with depths from 20 to 50 feet. Within twelve miles of the town of Fort Collins where the Agricultural College of Colorado is located, there has been over a million dollars invested in the construction of reservoirs during the past eight years, and this almost entirely by the farmers by voluntary assessment. The dams are almost entirely dikes of earth. In some cases in the west, masonry dams are built, but usually the conditions are favorable to the construction of earthen dams.

A question which naturally comes to the minds of those present is doubtless whether the system of irrigation might be applied in Michigan, and whether it would be profitable to do so. With a fair knowledge of the conditions of Michigan, acquired from having spent most of my life there, and having had occasion to investigate the conditions and possibilities of

irrigation, both as applied in the west and in other countries, I may say that I think there is every reason to believe that irrigation would be a profitable improvement in the agriculture of Michigan wherever it can be used. The conditions are in many cases not favorable. But wherever the conditions are favorable—the streams with sufficiently rapid flow and so located that water can be derived from them by means of canals—the practice would be beneficial and would be profitable to those who undertake it. In how many years of farming under natural rainfall, does not the profit disappear because of the losses due to drouth or from lack of moisture at some critical period in the growth of the crop. Irrigation becomes an insurance against losses and enables the farm to be kept to its maximum productiveness. It may be said that with the rainfall in Michigan irrigation is not needed. The rainfall is over twice that in Colorado, nevertheless it is less than the rainfall in northern Italy, where irrigation has been applied for time unknown and extensively applied for at least eight centuries. In the valley of the Po, the amount under irrigation has more than doubled since the middle of the present century, and schemes are projected which will bring large additional areas under the influence of irrigation. Wherever it is practiced, the amount of land under cultivation by irrigation is constantly increased.

The most serious difficulty to be met with in the Eastern states is the trouble that may arise between the persons who desire to divert water for irrigation, and riparian owners, or owners of mill rights, whose privileges may be interfered with by the diversion of the water. The passage of favoring laws would remove some of the difficulty, but not all, inasmuch as the courts are likely to maintain that the rights are vested and cannot be disturbed by legislation.

The President, Mr. Wells.—This paper involves a good many problems beside the one of irrigation, and is one which ought to call out quite a full discussion.

Speaking of the formulæ for the flow of water and the difficulty of understanding them, I have had a little experience in

that line during the last four or five years, as my work has been largely in the line of hydrulics. Most of the formulæ are empirical, and are simply shrewd guesses. I have spent considerable time in comparing the various formulæ and I have found in my practice, the tables in Trautwine's pocket book of the edition of 1893, about an average of all of them; I started using them when I first went into the hydraulic work, and thought I would work out a formula for myself, but these I have laid aside for the tables.

Trautwine's son has changed the formulæ on which his father's book was constructed, but I am still of the opinion that that is a fair average. Simpson's is also a good formula.

Mr. Rogers.—There is quite a change between Trautwine's new formula and the old book, is there not?

The President.—Quite a change in his co-efficient. He gives an extended table of co-efficients which can only be grasped after considerable study.

Mr. Rogers—I think it materially reduced the quantity of water that will flow through a pipe of a given size.

The President.—The old co-efficient as I remember was 54, and he has run down to the twenties and up to about sixty.

A Voice.—He has become a more scientific guesser.

The President.—As to the rainfall which Prof Carpenter speaks of, I have looked that up a little, in Pennsylvania.

I think that the rainfall for a decade, say, is quite even in any given locality, but you take the rainfall for one year with another, and you are apt to have more than you want some years, and less others.

The five years preceding this, at Du Bois, Pa., which is near the summit of the Alleghany mountains, the Government Observer there showed me his reports within the last three weeks, and the average rainfall for those five years was 44.1 inches, and on the 16th of December, I think it was, the rainfall for this year had been 31.61—nearly one-third short. We have had a gravity system of water works there, and we have had to pump seven months this year.

Mr. Sears.—44 inches in Michigan?

The President.—No, sir! Du Bois, Pa. The rainfall there is somewhat greater than in Michigan.

Mr. Sears.—I have a little garden. Last summer, I planted a small area in corn, about a rod in breadth and two rods long. On the morning of the fourth of July, my corn was drooping, and instead of going with the crowd and shooting off fire crackers, I thought I would shoot my hose. I went to work and made a little trench in each row—a sort of trough—and laid my hose on that and let it flow about fifteen minutes over every row; you ought to have seen that corn prick up its ears at once! I don't know but I robbed the city slightly, but it demonstrated to me the value of water in the warm weather of summer. I think you could quadruple the crop.

In leveling across the valleys of Missouri and Iowa, I learned this fact. You leave the bluff and go down into the main valley, and you will find a marsh, maybe 100 rods wide, and as you approach the stream you get on higher land, and near the main stream you will find it covered with timber, and perhaps find the land three to five feet higher than near the bluff. The stream is on an elevated plain and then changes its course, and near the base of the stream, builds that valley up. The Mississippi today is on an elevated plain, and by building these levees, you raise the river bed and when a flood comes, there is destruction far and wide.

Mr. Hodgman.—Isn't that general principle true of the rivers of Michigan?

Mr. Sears.—Yes, sir.

Mr. Hodgman.—I have talked to this Society ever since I came back from the west, that irrigation was a practical thing in Michigan, that it would be profitable in many instances, and the last two or three years of drouth in Michigan have emphasized the fact considerably.

As large a per centage of the land in Michigan as in Colorado, Utah or the arid region, is capable of being irrigated, and this subject will in the future occupy to a great extent the attention of the people of Michigan. They are going to irrigate.

Prof. Carpenter has discussed the manner of irrigating by

canals, and has incidentally spoken of storage reservoirs. Right there lies the solution of the irrigation question in Michigan.

There is a large amount of upland that you would say at first sight, could not be irrigated, that could be irrigated if we will impound the water. Will it pay to do it?

I have a little place of about ten acres, and there are two or three hollows in it. Last March the water came down and in the deepest hollow, there was water six feet deep. Then the dry season came on and ruined my crops. If I could have had that half acre of water that went to waste, to use in the summer, I could have saved my crops.

Let us utilize the streams as far as we can; next, build impounding reservoirs, and use them as far as we can.

In the west, a good deal of land is irrigated by wind mills. They dig a well, put in a windmill and set it going. A man from near where I live, has a large tract in California which is irrigated solely by wind mills. I don't know how much of that is practicable in the State of Michigan, but there is no sort of question that it is possible to a certain extent. It is simply a question of dollars and cents. Will it pay?

Another thing, we have in Southern Michigan, and perhaps all over the State, a large amount of what we call "swamp land." The last few years have proven that this is the richest land in the state, but that it wants not only drainage, but also irrigation. They must go together. You can drain out these swamps to such an extent that they will be of little value, but if in connection with your drainage, you fix it at the same time so that you can stop the water and wet the land, then you have the ideal conditions.

One member of this society wrote me this winter, that last year he spent five weeks designing a drainage system for A. M. Todd, the Peppermint King, who has bought several thousand acres up in what is known as the Clyde Swamp. I went there myself once and I never want to go there again.

Judge Severens of the United States Court, bought something over 5,000 acres of land and I made the surveys for him. He has brought a large amount under cultivation and last year

he had something like 10,000 pounds of peppermint oil and ten thousand bushels of onions off of this swamp land.

Mr. A. M. Todd has purchased a large amount of this peppermint land and O. H. Todd is putting in an irrigation system for him. It strikes me that the irrigation of the State of Michigan is work for the engineers to do, and work that will be valuable to the people of the state.

Mr. June.—What is the condition of the swamp lands after they have been drained—are they too dry?

Mr. Rogers.—Unfortunately I have not been, for the past four or five years, through the lands where I did so much work—not since the drains have been in successful operation. As far as my observation goes, where the muck was deep, the drains have made it so dry that the lands produce almost nothing. Where the subsoil was clay, and the clay turned up a little with the plough, they have not met with this difficulty; if there were any way of damming the ditches, it would be of immense advantage, but the trouble with that land is that a large portion of it is nearly level. Some of these ditches are laid with a fall of only two feet to the mile, and if you attempt to dam them, you are in danger of completely spoiling the land you are trying to reclaim. The land is too level there for this to work.

Mr. Hodgman touched upon a point of which I had been thinking; whether it would be possible to irrigate with wind mills. There are many farmers throughout the state who use wind mills for pumping water for their stock, and they are not run to anywhere near their full capacity. If they had wells with capacity to run these mills longer, and could arrange to use the water to irrigate their farms, I think it would be advantageous.

Mr. Sears.—The only way to prove that would be by experiment.

Mr. Wells.—Between Saginaw and Bay City are some tracts of land of considerable extent which have been dyked, and from which the water is pumped. My observation has been conducted from a car window mostly, but I imagine they have been flooded considerably; but last summer I saw a very

simple contrivance, on the plan of a centrifugal pump operated by a portable engine, and they were pumping water out of the trenches onto the ground. There are probably some gentlemen who live here in Saginaw who have been connected with these improvements.

Mr. Holmes.—I have had no experience in the work of reclaiming land, as an engineer, although I am familiar with this method of reclamation. In one instance, the proprietor was not an engineer, and I think the contractor who did the trenching, wrote the specifications. All that was done was simply to throw up a dyke, and then pump out the water, and the reclamation seems to be complete and satisfactory. There was one place where it was unusually wet and we laid tile, and it was very efficacious in the removal of water.

Mr. Hodgman.—I want to say a few words in regard to the point raised by Mr. Rogers, in regard to these flat lands. Nearly all the celery lands in Kalamazoo County are that flat kind of land. They irrigate there almost entirely; they dam up their ditches when it is dry enough to need it and let the water flow back in the tile drains, which lead into the main ditches, and in that way the water is distributed.

The fact that there is little fall is not an objection to irrigating these flat lands. It is sub-irrigation.

The President.— Mr. Holmes, have you made any observation as to the extent to which this method of irrigation has been employed between here and Bay City, and with what degree of success the enterprise has met?

Mr. Holmes.—No sir, I don't know anything about that.

Mr. Hodgman.—Nearly all the flat lands in our vicinity—and there are many of them—are irrigated by stopping up the ditches and sending the water back. It is not surface irrigation, it is sub-irrigation. The largest crops we have had for years were raised there this past year, when on the uplands crops were very light. A neighbor of mine had 175 baskets of corn to the acre on the low land, while on the upland he didn't get 40. Supposing in that case I spoke of, that I had a reservoir that filled up in the spring and had a pump there, attached to an ordinary traction engine, wouldn't it have been practica-

ble to irrigate my land? Or would the expense have been so large that it would not have paid?

Mr. Wells.—The expense of lifting water at these low levels with a centrifugal pump is slight. There has been a pump used to a considerable extent in the South, with which they raise water ten feet, and the horse power is so small that the expense is very slight. The question of impounding water in such shallow depths, must be figured on with due regard for evaporation; it can best be stored in the deepest hollows. If a little damming of the outlets would tend to raise the water, it would pay to do that. On warm days, the water evaporates about ⅛ of an inch per day, in shallow ponds.

Mr. Hodgman.—That is a general guess I suppose.

The President, Mr. Wells.—Trautwine's observations are actual, but it would be subject to such varying conditions that you would perhaps hardly find another instance just like it, though that seemed to be a good average. He mentioned some specific cases in which this was so, and I think those were in some states further south than this.

Mr. Hodgman.—Perhaps Prof. Vedder can tell us something about irrigation at the Agricultural College.

Prof. Vedder.—I know very little myself, in regard to the matter. The experimental part is at the water supply end, but I have no question that it has cost more than it is worth to raise the water there.

Mr. June.—I am convinced that the cropping scope, as you might say, of irrigated lands north of Saginaw, would be about divided by two, from the fact that it would be necessary in my judgment, to raise only the crops that would resist frost. That the frosts are much worse on the low lands is well known and my observation has been that wherever crops have been placed on the low land, and were crops that would suffer from frosts, they have been destroyed. In the low lands which I have drained, the crops which succeeded were crops that were not easily injured by frosts; this would exclude, to a great extent, corn from these lands. If the higher land could be irrigated, by storage or any means, of course our season would

permit of a greater range of crops, and perhaps a great deal more profit.

In regard to the question I suggested to Mr. Rogers, in regard to the drying of the lands—the low lands—my observation has been that the ditch only dried the land to about the depth of the ditch, and the lands would draw the water still, but that was only in certain cases where the land was what we termed springy—it was deeper muck and more water on the lands, and the ditches only drained the surface of the land. Of course in an excessive drouth and in more cleared up country, the sub-irrigation idea would be splendid, but in the northern part of the state, I think that about half of the crops would be excluded.

RIPARIAN RIGHTS.

BY HUGO P. GEISLER.

Mr. Chairman and Gentlemen of the Michigan Engineering Society:

I was requested by the secretary and members of your Society, to read before you a paper on the riparian rights of property owners respecting the location of their boundary lines.

I beg to thank you for the honor you have thus done me, and shall endeavor to present such facts bearing on the subject as I hope may prove of interest to you.

Perhaps there is not a more difficult question to answer in all the law of real property. The English common law rule was that all streams, in which the tide ebbed and flowed, were navigable streams, and all the others were non-navigable.

3 Washb. R. P. 413.
People vs. Tibbetts, 19 N. Y., 523.
Commonwealth vs. Chapier, 5 Pick. 199.

In England this is not, as a matter of fact, the arbitrary rule which it would be, if applied without qualification to the streams of this country. With the exception of the Thames, above tide water, there are no important streams in England which are practically and actually navigable, except those in which the tide ebbs and flows; and there are no tide water streams of any importance which are not actually navigable.

But in the United States the situation is altogether different. Here we have fresh water streams which are navigable, and salt water streams of great value, which are not navigable. The application of the common law rule in this country would, therefore, result in nothing but absurd conclusions. The courts of this country have been discussing the problem for many years, and have come to different conclusions on the various branches or subdivisions of the question. On only one point is there an absolute agreement, viz: That the common law rule does not govern such questions in the United States, so

far as the right of the public to navigate the streams is concerned. That is, the courts hold uniformly that where the streams are sufficiently deep and wide to float boats, used in the interest of commerce and agriculture, the public has a right to use them as highways.

But, in whom is the title of the soil of the river's bed or in what rivers does the state hold the title to the bed, is differently decided in different courts.

The courts are unanimous in holding that ordinarily, where the tide ebbs and flows, the title to the bed of the stream is in the state.

Tied. R. P. 835.

But the state does not own the soil or bed of every creek in which the tide ebbs and flows. In order that the title to the soil of such creeks may be claimed by the state, the creeks *must* be practically navigable.

Rowe vs. Granit Bridge Corp. 21 Pick. 344.
Glover vs. Powell, 10 N. J. Eq. 211.
See State vs. Gilmanton, 14 N. H. 467.
Wilson vs. Forbes, 2 Dev. 30.
Am. River, etc., Co. vs. Andrews, 6 Ca. 1443.

But in respect to the title to the bed of fresh water navigable streams the courts are divided. A number of the courts have held that the fresh water streams are governed by the common law rule, in respect to the title to the soil under navigable streams, and that the title to the bed of the fresh-water streams is in the state.

Barney vs. Keokuk '94 U. S. 324.
McMauris vs. Carmichail, 3 Iowa; 1.
Shrunk vs. Schuylkill Co., 14 Serg. & R. 71.
Martin vs. Evansville, 23 Ind. 85.

The Supreme Court of Mississippi, in a very able and learned opinion, drew a distinction between public and navigable rivers.

It was there asserted that the principle, that the title to the soil of navigable rivers, i. e., rivers in which the tide ebbed and flowed, was in the State, was derived from international law. Tidal waters are the highways of nations, and very properly the title to the soil or beds of such streams was vested in the State. But where the navigable river is a fresh water

stream, although a sound policy would require a grant to the public of a right of way over it; there is no reason why a distinction should be made between them and non-navigable streams, in respect to the location of the title to the soil. It was, therefore held that the public have a right of way over fresh-water streams which can be navigated, but that the title to the bed is in the riparian owners, and the boundary line is its center line of the stream.

Steamboat Magnolia vs. Marshal, 39 Miss. 109.

The rule that the title to the beds of those rivers is in the riparian owners is supported by the following authorities:

Ryan vs. Brown, 18 Mich. 196.
People vs. Bratt, 17 Johns. 195.
O'Follow vs. Daggert, 4 Mo. 343.
Rhodes vs. 33 Ala. 578.
Canal App. vs. Wilkins, 4 Pick. 268.
Claremont vs. Carlton, 2 N. H. 369.
Blanchard vs. Porter, 11 Ohio, 139.
Berry vs. Snyder, 3 Bush. 266.
Ensminger vs. People, 47 Ill. 384.

The Supreme Court of the United States has held that the rivers, which from their location constitute the boundaries of States, and which are used, or may be adopted for use, in interstate and foreign commerce, are navigable streams of the United States.

The Danial Ball, 10 Wall. 557.
The Montello, 11 Wall. 411.

Let that be the controlling principle, and declare the title to the bed of such streams to be in the riparian States, in conformity with the decisions of the United States Supreme Court. Those streams might very properly be classed among the highway of nations, for the States in this connection are to be considered as separate and independent bodies politic. But the intra-territorial streams cannot be called international highways, and, therefore the title to the soil of such should be vested in the riparian owners, subject to the public easement of navigation.

Generally where land is bounded by a stream which is not navigable, the boundary line is the centre line of the stream, the *filum aquæ*; and the line changes its course with the natural and gradual change of the current.

Tied. R. P. 833.

But it does not always follow that the thread of the stream will be the boundary line, because the stream is referred

to in the deed. If the stream is mentioned as the boundary in general terms, or the land is described as "bounding on" or "running along" a river, the stream will be held to be the monument and the thread of the stream is the boundary line. And this is true although the deed describes the line on the stream as extending from one object to another, both of which are on the shore, as for example, "bounding on" the stream and "extending from." one tree on the bank to another. The termini of the boundary line are ascertained by drawing lines at right angles with the shore from these objects to the centre of the stream.

Lunt vs. Holland, 14 Mass. 150.
R. R. Co. vs. Schurmeir, 7 Wall. 286.
Cox vs. Fredly, 38 Pa. St. 129.
Commonwealth vs. Alger, 7 Cush. 97.
Brown vs. Chadbourn, 31 Me. 9.
Newton vs. Eddy, 23 Vt. 319.
McCullough vs. Aten, 2 Ohio 425.

But if the land is described as bounding "on the bank" or "shore" of the stream, then the low water mark on the banks will be the boundary. The particular reference to the bank excludes the stream.

Watson vs. Peters, 26 Mich. 516.
Child vs. Starr, 4 Hill. 369.
Daniels vs. Cheshire R. R. 20 N. H. 85.
Bradford vs. Cressy, 45 Me. 9.
Halsey vs. McCormick, 13 N. Y. 296.
Martin vs. Nance, 8 Head. 650.

Where the stream or its bank is the boundary line, it follows its meanderings, so that if the distance is given it is ascertained by reducing the irregular lines of the shore to a straight line.

Calk vs. Stribling, 1 Bibb. 122.
Hicks vs. Colman, 25 Cal. 122.
People vs. Henderson, 40 Cal. 32.

Where the land is bounded by a navigable stream strictly so called, i. e., where the tide ebbs and flows, the boundary line is the high-water mark on the shore.

Canal Comm. vs. The People, 5 Wend. 423.
Wheeler vs. Spinols, 54 N. Y. 377.
Niles vs. Patch, 13 Gray 254.
E. Haven vs. Hemingway, 7 Conn. 186.
Stewart vs. Fitch, 30 N. J. L. 20.

Where riparian estates are conveyed, the owner may reserve the land under water, but the general presumption is that the purchaser's title extends as far as the grantor owns, in both tidal and fresh waters.

The legal effect of the conveyance is determined by the terms employed, and cannot be controlled by parole testimony,

unless there is a latent ambiguity, or the description itself is rejected as false, or the identical boundary referred to in the conveyance is in dispute.

While the common law of England is supposed to govern us in laying a foundation for decisions in this matter, it must be remembered that the common law of England is not to be taken in all respects to be that of America.

Our ancestors brought with them its general principles and claimed it as their birthright, but they brought with them and adopted only that portion which was applicable to their situation.

Perrin vs. Lapper, 35 Mich. 292.

And since the common law has been modified in the different states so as to be applicable to their local situation, and it not being uniformly modified throughout the country, in determining the riparian rights, we must ascertain the law of the states within whose territory such lands are situated.

It is a well settled rule that the common law of England is in force in Michigan, and questions of property not clearly excepted from it must be determined by the common law, modified only by such circumstances as render it inapplicable to our local affairs, and especially in relation to the present subject matter.

The ordinance of 1787 (Art. 4.) for the government of the north-west territory, providing that "the navigable waters leading into the Mississippi and St. Lawrence rivers, and carrying places between the same, shall be common highways and for ever free, as well as to the inhabitants of said territory as to the citizens of the United States, and those of any other states that may be admitted into the confederacy without any tax, impost or duty, therefore, etc.," has been construed by the Supreme Court of the United States to vest in the several states the ownership of the bed of navigable waters.

R. R. Co. vs. Schurmeier, 7 Wall. 272.

The ownership of the soil under navigable water being in the state within whose territory such lands are situated, the decisions of the several state courts must be consulted to determine whether or not in any particular instance the riparian

owner on a navigable stream owns to the thread of the channel.

The question that now confronts us, is, what is the law of this state in respect to the title to the soil of the fresh water streams, ponds and lakes?

The right of riparian owners are nowhere mentioned in the ordinance of 1787, or in the acts admitting Michigan into the Union. The same being left to be settled according to the state law.

How. Stat. p. 29, Art. 4. Moore vs. Sanborn, 2 Mich. 519.
Burroughs vs. Whitwan, 50 Mich. 279. Webber vs. P. M. B. Co., 62 Mich. 627.
Benjamin vs. Manistee R. Imp. Co. 42 Mich. 628.

Where the land abuts and bounds upon a fresh water stream or river there is no question, and the law in such cases is perfectly plain and it is the settled law in Michigan that the title of the riparian owner extends to the middle line of the stream or inland lake,

Lorman vs. Benson, 8 Mich. 18.
Webber vs. Pere. M. B. Co., 62 Mich. 626
and cases cited on page 636.

and the current is not essential to the existence of riparian rights. They may exist in lakes or ponds where there is no current, and they may exist where the water is not capable of navigation.

Turner vs. Holland, 65 Mich. 453.

The rule has been one of property, in Michigan, and the United States Supreme Court has repeatedly held that it is the right of each state to determine the doctrine for itself.

Barney vs. Keokuk, 94 U. S. 324.
Hardin vs. Jordan, 140 U. S. 371.

If the channel of the river is divided equally by a middle ground or island, then the boundary line of each proprietor is a line running parallel with the course of the river and dividing the island into two equal parts. If the channel is divided unequally, then the smaller channel is ignored and the boundary line is the thread of the main channel.

Watson vs. Peters, 26 Mich. 518. Fletcher vs. Thouder, B. B. Co. 51 Mich. 277.
Crocker vs. Brogg, 10 Wend. 260. Trustee vs. Dickinson, 9 Cush. 548.

If such middle ground is owned by a third person, such person is a riparian owner as to each of the proprietors on the river, and the boundary line between his land and the land of each of

them is the thread of the channel between the middle ground and the main land.

People vs. Canal App. 13 Wend. 355.

Little difficulty is experienced in ascertaining the boundary line and riparian rights of the adjacent owners to narrow streams, and the rule recognized and approved in Michigan in determining boundary lines between adjoining riparian owners is that, "where the stream is straight, the water front will be the boundary by lines drawn at right angles with the thread of the stream, protracted until they reach the end of the shore line.

Where the stream curves the same principle applies, and the lines running from the shore would converge or separate, according as the land lay within or without the curve. In all the cases where the ownership of the submerged land or of alluvial increments, appurtenant to riparian ownership, has come in question, the only elements of which have ever been considered by the courts, have been the shore lines and the central line or thread of the stream, and the partition among adjoining owhers has been made with reference to those, but never with any reference whatever to the direction of the boundaries or the extent of the domain on upland.

The aim in every instance has been to secure to each owner such share as was indicated by his shore line, and not by his lands back of it.

Lorman vs. Benson, 8 Mich. 18. Rice vs. Ruddiman, 10 Mich. 125.
Clark vs. Campau, et al., 19 Mich., 323, and cases cited on page 329.

In ascertaining the boundary lines and rights of riparian owners of lakes and ponds the difficulties one must contend with are more numerous, and relate mostly;

1st—To the impossibility of defining the boundaries where there is no *filum aquæ*;

2nd—The public characters of the waters which give the state much larger control than over strictly private waters, and

3rd—In fractional subdivisions of land.

In this country a distinction is made between public and private lakes, depending upon their size and value for purpose of navigation.

Rice vs. Ruddiman, 10 Mich. 125.
Verplank vs. Hall, 27 Mich. 79.
Lincoln vs. Davis, 53 Mich. 365.

The riparian rights on the Great Lakes, are, in theory, the same as upon navigable streams, and are not governed by any such proprietory division as high and low water mark. The submerged lands are appurtenant to the up lands so far as their limits can be reasonably identified; but in public waters the state law must determine how far right in such land can be exercised consistently with the easements of navigation.

The state can forbid any erection in navigable waters, and on navigable streams, and along the great lakes can fix the distance beyond which private erections cannot be maintained.

Lincoln vs. Davis, 53 Mich. 375.

Although by the common law under the grant of lands bounded on a lake or pond which is not tide-water, and is not navigable, the grantee takes to the center of the lake or pond, ratably with other riparian proprietors, if there be such.

Hardin vs. Jordan, 140 U. S. 371.

Grants by the United States of its public lands bounded on streams and other waters, made without reservation or restriction, are to be construed as to their effect, according to the law of the state in which the lands lie, and as heretofore stated, it depends upon the law of each state to what extent the prerogative of the state to land under water shall extend.

Hardin vs. Jordan, *supra.*

The question often arises as to the title in reference to the lake and the bed of the lake in front of the land actually described in the grant.

It has been the practice of the government from its origin in disposing of public lands, to measure the price to be paid for them by the quantity of upland granted, no charge being made for the lands under the bed of the stream or the body of water.

The meander lines along or near the margin of such waters are run for the purpose of ascertaining the exact quantity of upland to be charged for, and not for the purpose of limiting the title of the grantee to such meander line.

It has frequently been held by the courts of this state, and the United States Supreme Court, that such meander lines are

not intended for the purpose of bounding and abutting the lands granted upon the waters whose margins are thus meandered; and that the *waters themselves* constitute the real boundary and that the private ownership of lands bounded on navigable water is not restricted to the meander line.

R. R. Co. vs. Schurmeyer, 7 Wall. 272.
Pere Mar. B. Co. vs. Adams, 44 Mich. 43.
Jefferis vs. E. Omaha L. Co., 134 U. S. 178.
Clute vs. Fisher, 65 Mich. 48.

In Clute vs. Fisher, the court held that, "the owner of a fractional subdivision of land, made so by an inland lake, owns the soil under the water of said lake which would be included within the subdivision if its lines were *fully* extended, and can maintain trespass against any one who cuts and removes the ice formed over *such* soil without his consent."

This principle was based upon the case of Palmer vs. Dodd, 64 Mich. 475; Wilson vs. Hoffman, 54 Mich. 246, and Keyser vs. Sutherland, 59 Mich. 455, which cases were based upon Brown's Lessee vs. Clements, 3 How. 650, in which cases the court held that, "No grantee by a patent, granting a legal subdivision of land, can derive title to land upon another legal subdivision."

The case of Brown's Lessee vs. Clements, upon which the Michigan decisions were based was overruled in Gazzan vs. Lessee of Philip, 20 How. 372.

In Grand Rapids Ice & Coal Co. vs. South G. R. I. & C. Co., 60 N. W. 681, the inconsistency of the rule set forth in Clute vs. Fisher with the rule repeatedly laid down in this state, "that the shore proprietor owns to the center of the stream," is set forth.

The court says: "It is also inconsistent with the rule laid down in Clark vs. Campau, 19 Mich. 328, and Bay City Gas Light Co. vs. Industrial Works, 28 Mich. 182, that side lines are to be governed by the course of the stream and the submerged land bounded by lines drawn at right angles with the central thread, rather than at right angles with the shore at the point of departure." Again the rule that a conveyance of a fractional subdivision actually conveys the entire subdivision

is inconsistent with the rule laid down in Boon Co. vs. Whitney, 26 Mich. 42; Dart vs. Barber, 32 Mich. 271; Jones vs. Pashby, 62 Mich. 614; Hartford Iron Min. Co. vs. Camboia Min. Co., 80 Mich. 491.

In each of these cases part of a parcel of land having a water frontage was conveyed, described it as one-half of the lot or parcel; and it was insisted that the conveyance was of one-half of the water frontage, but the court held that the words "half of the lot" meant "half of the quantity of upland." A correct result was given in the Clute case, but the reasons given are without support.

The reason the result is correct in the Clute case is because the meander lines were almost wholly and the water lines were wholly within the subdivision owned by Clute. And that "no claim was made that an apportionment would give the right to cut the ice to some one other than Clute, but the sole contention was that the title to the bed of all the lands within the meandered lines was in the state. And it was that question the court was dealing with."

Many of the decisions relating to, and the doctrine of riparian rights, are quite fully discussed in Grand R. I. & C. Co. vs. S. G. R. I & C. Co., by the learned Chief Justice McGrath, and on page 684 the court says, that: "The shore proprietor takes by virtue of shore ownership. His interest in the bed of the stream he acquires as appurtenant to the grant, and the extent of that interest depends upon his frontage, and the form, length and breadth of the body of water upon which he abuts. That the lake may be of such form as to render the designation in it of the boundaries of the several riparian owners somewhat difficult, is not an objection to the application of the rule."

In Lincoln vs. Davis, *supra*, Mr. Justice Campbell, in laying down the rule of lines of ownership on lakes, says: "On lakes all lines from the shore tend to converge in some central part of the lake; and while irregularity of shape prevents drawing them to a common center, they must all, if protracted, cross each other in a perplexing way. The rule adopted in such waters where the whole surface could be appropriated,

has always been to divide the water area in proportion to the shore frontage, and never to attempt any division by lines run from the shore, except over such parts of the lakes as are substantially adjacent to the shore. In some cases by a fair partition, a shore owner by his extent of shore line, may obtain a share beyond the center. But it seems impossible, if the whole water is to be regarded as divided up, to reach a division without some proceedings in the nature of a partition, which will fix the various possessions."

The G. R. I. & C. Co. vs. S. G. R. I. & C. Co., where the controversy was over the right to cut ice in Reed's lake, plaintiff insisting upon ownership of the bed of the lake within the lines of the fractional subdivision extended, and the defendant insisting upon a division of the center line proportionate to the shore line, so as to give to each riparian owner an equitable share, the court say, that "where a navigable lake of such size that entire sectional subdivisions are included therein, the owner of a fractional subdivision of a section, meandered by the United States survey along the margin of the lake, does not own all the lake lying within the extended lines of his subdivision," and is governed by the rule laid down in Johnson vs. Lee, 77 Mich. 35, in which Mr. Justice Campbell on page 40, says: "It appears clearly enough in the present case that while there is a considerable frontage facing north-west and south-east, the lake being longest in that direction, there must also be large frontages, which look up and down the lake perpendicularly, or nearly so, to any line across from bank to bank, and most places along the shores. If this body of water were not navigable, and if all its waters could in any way be apportioned among the riparian proprietors for any lawful purpose, it is evident that it could not be done by any reference to any *filum aquæ* or middle thread, but must be done by some rule of proportion, which probably could only be got at by some partition proceedings, inasmuch as such waters are common for all ordinary uses, unless it may have been placed in a different position by the public surveys, as has been done in many instances of small so-called 'lakes' not navigable."

In B. & D. Lumber Co. vs. Peters, 87 Mich. 498, where the

complainant and defendants were adjoining owners of parcels of land bordering upon the waters of Green Bay, which is a part of the waters of lake Michigan, and navigable for all classes of vessels, both parties owned and operated saw mills, and constructed wharves to the deep water of the bay, upon which to pile and from which to ship their lumber. The question in dispute related to the subdivision line of their respective holdings under the waters of the bay, and in deciding the case, the court say (on p. 506-7); "Upon consideration of the authorities cited, we think the rule adopted in Massachusetts will, in cases like this, secure a nearer measure of justice than those adopted by the courts of any other state. We cannot deal with Green Bay as we could with a river in this state, where the lines are to be drawn at right angles to the thread of the stream. The rule laid down for the boundaries of owners of land bordering upon the ocean and great inland seas are more proper for the disposition of the case before us. The rule defined in Massachusetts is:

1st—To measure the whole extent of the ancient bank or line of cove or bay, and compute how many rods, yards, or feet each riparian owner upon such line has.

2nd—To divide the newly formed line into as many equal portions as those contained in the shore line, and then draw straight lines from the point at which the proprietors respectively bounded on the old to the points there determined as the points of division on the newly formed line."

It is freely admitted that this rule may require modification under particular circumstances in order to secure equal justice, and that, in ascertaining the shore line or margin of the water, a general line ought to be taken, and not the actual length of the line on the margin, if it happens to be elongated by deep indentations or sharp projections, so that the line shall embrace the general available line of the shore. This is exactly what the meanders run by the United States government do.

The lines are run straight, disregarding indentations and projections which are not available for any general useful purpose.

"The object to be kept in view in cases of this kind is to secure to each proprietor access to navigable water and an equal share of the dockage line of navigable water in proportion to his share on the original shore line." In Hardin vs. Jordan, *supra*, where the subject of riparian rights has been very ably and exhaustively treated, and where the Roman, English and American authorities have been very carefully considered, and to which I invite your attention, the court on page 402 say: "If there shall arise any question between the plaintiff and other riparian owners of land situated on the margin of the lake, as to the convergence of the side lines of the plaintiff's land in the lake, it can be disposed of by the parties themselves by a resort to equity or to such other form of proceedings as may be proper."

I have not cited any Massachusetts or Maine decisions in support of the position above taken in reference to the title to the soil of lakes, for the reason that in those states they are governed by a Massachusetts ordinance passed in 1647, which makes all lakes of more than 10 acres extent public, and therefore deny that ownership of such lakes extend to the center.

The decisions of the courts in other states, which deny private ownership of the bed of small lakes, are mostly based on the Massachusetts and Maine decisions and have cited them in support of their position, perhaps not realizing or recognizing the fact that they are governed by the Massachusetts ordinance.

Since it is the well settled rule, that, at common law the riparian owner takes to the center of the stream, or other waters that are non-tidal, and that the meandered lines are not the boundary lines, it is held that, when the United States has disposed of the land bordering on the meandered lakes by patent, without reservation, or restriction it has nothing left to convey, and any patent thereafter conveyed for land forming the bed of the lake, or former bed, is void and inoperative.

Lamphrey vs. State, 18 L. A. R. (Minn.) 670.
Hardin vs. Jordan, *supra*.

However, it has never been held that the lands under water in front of such grants, are reserved to the United States.

or that they can be afterwards granted out to other persons, to the injury of the original grantors. To attempt to make such grants is calculated to render titles uncertain, and to derogate from the value of natural boundaries, like streams and bodies of water, and it is well settled that the grantee takes the fee with all the riparian rights incident to the ownership of riparian land, including the right of accretions and relictions.

With regard to grants of the government for lands bordering on tide water, the court in Hardin vs. Jordan, *supra*, on page 381, say: "It has been distinctly settled that they only extend to high water mark, that the title to the shore and lands under water in front of lands so granted enures to the state within which they are situated, if a State has been organized and established there."

Such title to the shore and lands under water is regarded as incidental to the sovereignty of the State—a portion of the royalties belonging thereto and held in trust for the public purposes of navigation and fishery—and cannot be retained or granted out to individuals by the United States.

Pollard vs. Hagen, 3 How. 212.
Gootitle vs. Kibbe, 9 How. 471.
Webber vs. Harbor Com. 18 Wall 57.

Generally speaking the true meander line of a navigable stream or lake is the point to which the water usually rises in ordinary seasons of high water. In a question of boundary the position of that line is a question of fact for the jury; and it controls, although the meander line of the survey is found not to be coincident therewith.

Gould on Waters, Sec. 76.

In fixing private right or lines, "a surveyor cannot be allowed under any circumstances, to fix private rights or lines by any theory of his own. Before a surveyor's evidence can be received at all, it must be connected with the starting points and other places or lines called for by the grants under which the parties claim. His duty is neither more nor less than to measure geometrically in accordance with those data, and his science goes no further. It is not his business to decide questions of law, or to pass upon facts that belong to the tribunal

dealing with the decision of fact. His testimony as a man of science, is never receivable except in connection with the data from which he surveys, and if he runs lines they are of no value unless the data are established from which they are run, and those must be destinctly proven, or there is nothing to enable any one to judge what is the proper result."

Jones vs. Lee, 77 Mich. 43.

In conclusion, gentlemen, I desire to thank you for your kind attention, and while I have not treated this subject as fully as one might, I trust that what I have stated will be of benefit to you. HUGO P. GEISLER.

Saginaw, Mich., Jan. 7th, 1896.

Question submitted by Mr. Courtright.

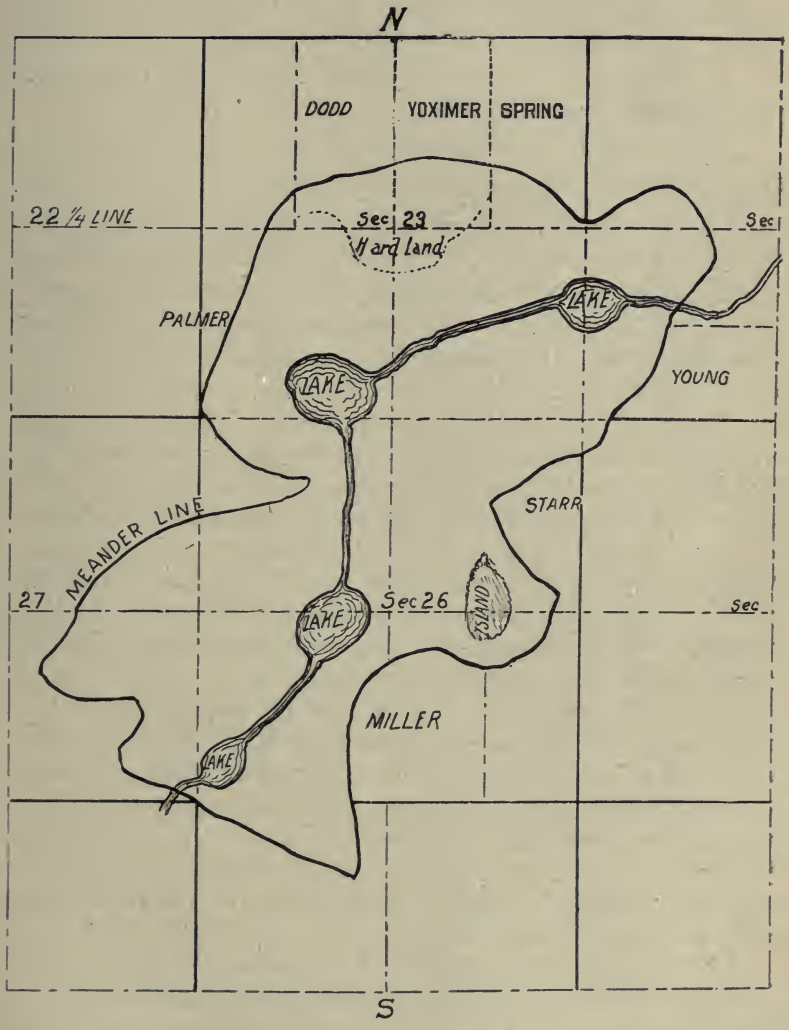
Mr. Hodgman.—Over in the country spoken of by Mr. Courtright, there is a tract of country that is represented in the field notes and plat of the United States survey, as being a lake, and it covers a considerable part of several sections. But in fact, instead of being one large lake, covering a considerable tract of territory, there were three little lakes there, connected with a stream (illustrated by diagram).

Some years ago, a man by the name of Palmer, owned the S. E. ¼ of Section 22, and land adjoining it in Section 23. Part of what is represented as lake in the S. W. ¼ of Section 23, was really hard timber land. Mr. Dodd, who owned the E. Fractional ½ of N. W. ¼ of Section 23, undertook to take the timber and Mr. Palmer claimed it, and they had a law-suit and Mr. Palmer held it. Now the question comes up in regard to the S. E. ¼ of Section 23. The United States have never given any title to it directly, supposing it was all water; they never have given any patent to the S. E. ¼ of Section 23. Now who owns it? Do the parties, adjoining the lake on each side, own it, or if not, who does?

Mr. Rogers.—What are those squares? (referring to diagram). Do they represent quarter sections?

A. Yes sir.

Q. But the hard land that is represented in the Government Survey, is that known as a fractional quarter?


N
DODD
YOXIMER
SPRING
22 1/4 LINE
Sec 23
Hard land
Sec
PALMER
LAKE
LAKE
YOUNG
STARR
MEANDER LINE
27
ISLAND
Sec 26
Sec
LAKE
MILLER
LAKE
S

A. I don't know about that. I presume it was sold as fractional quarter sections.

Q. The whole line of the larger circle there is a meander line?

A. Yes sir. The S. E. quarter of 23 is not in the market. The question is, who owns it?

Prof. Geisler. The Government only uses a meander line for the purpose of measuring the upland. The rule is that they charge for only the hard land, but under the ordinance for the regulation of the N. W. Territory the Courts have construed repeatedly that the United States cedes the land under water to the State. Now the question arises, does the State cede the right to the title of the land under the water to the shore owner?

We have adopted the common law in this State, which makes all waters that are not tide waters, non-navigable, and the title to the thread of that water belongs to the riparian owner. To apply that here, we have modified the common law rule, as applicable to our local affairs. I would then say that we ignore the meander line, and if this part has never been conveyed by patent of the United States, the riparian owner would go beyond the meander line and take the soil under the water and have title to it.

Now the question is to divide it by boundary lines. It covers more than one section and you could not apply to it any of the State rules. You would have to have a partition suit and if the adjoining owners could not agree among themselves, you would have to have it settled by a Court of Equity.

Mr. Courtright.—The Supreme Court held that Dodd could not cross that quarter line.

Mr. Geisler.—That position is emphatically wrong. The decision of Dodd vs. Palmer was based upon two other Michigan cases, and if I remember aright they were based upon some Massachusetts doctrine, which was governed by an ordinance which was only applicable to the New England States, and it has misled a great many states in this country, and I

think if that Dodd case was ever brought up again, that the Court would make another ruling.

Q. Supposing Palmer's deed covers the S. W. Fractional quarter, and Dodd's deed covers the N. W. quarter, why should Dodd hold on the S. W. quarter?

Mr. Geisler.—Now you say the Palmer deed calls for the S. W. quarter of 23. The entire quarter section?

Mr. Courtright.—Palmer's deed calls for the S. W. fractional quarter of 23. Dodd's deed for the East half of the N. W. fractional quarter. Why should Dodd be allowed to hold on land that Palmer's deed covers?

Mr. Geisler.—For the reason that when this land was meandered by the United States, this was water— considered so by the Government—the Government was not selling the water, but simply the land which was really in existence and they were charging for that particular part. He buys that particular land, subject to all its riparian rights, in conformity with any other riparian owners there, and the rule would then be applied that they would have to divide their land according to whatever would be just.

Mr. Courtright.—That would be, with the understanding that the Dodd and Palmer case was decided wrongly.

Mr. Geisler.—It was wrong, unless there was an irregularity in the survey, and a positive showing that the United States corrected the meander line before they deeded the property. Now the State claims to have no title to the S. E. quarter of 23. The title should be divided according to the rules laid down, by actual measurements, and if they cannot be applied, you would have to have a partition suit, and that would be decided according to the frontage of the individuals.

Q. What would be the direction of Dodd's west line, after it crosses the quarter line? Would it be produced, or in a different direction?

Mr. Geisler.—Necessarily a different direction, owing to the surrounding lines. I do not think it would be a straight line. Of course that would have to be figured out, according to the frontage of each individual.

Q. In your opinion, would it be likely to apportion that

area within the meander line in the same ratio as they hold lineal feet in the meandered area?

Mr. Geisler.—I think that would be followed in a partition suit, but you could not follow it by any set rules of survey.

The President, Mr. Wells.—Some time ago, I read of a decision in a case like this: A man buys this fractional piece of land and the water rights, and the decision was that he could only claim within the boundary lines of that fraction.

Mr. Geisler.—That has been gone back on.

Mr. Hodgman.—It may not perhaps be out of the way, at this point, since President Wells has raised the question, to say that the Michigan Engineering Society had something to do with bringing about the reversal of the Supreme Court decision, Clute against Fisher, in which the Supreme Court decided that the parties held out to where their boundary lines would have been if there had been no water there.

At a session of our Society, held at Kalamazoo in 1887, that decision, as well as the Wilson-Hoffman case, was criticised by our Society.

These decisions, as well as the Palmer vs. Dodd case, brought up by Mr. Courtright in his question, were all based on a decision of the Supreme Court of the United States in the case of Brown's lessees vs. Clements, 3rd Howard, 650. This was a case brought up from Mobile, Alabama, and decided in 1845, and it was held that the party holding the patent to the S. W. ¼ of Sec. 22, containing 92.67 A. was entitled to an entire quarter section, although the official plat showed it to be fractional and another party had the patent to the S. E. subdivision of it. In 1858 the same tract of land came into controversy again, and it was brought the second time before the Supreme Court of the United States in Gazzam vs. Phillips, lessee. This time the court reversed the decision in the Brown vs. Clements case, saying that it was contrary to their own previous decisions and to the uniform practice of the Land Department of the United States for thirty-eight years, and that less harm would result from reversing the decision than from following it.

The Michigan Engineering Society called the attention of the Supreme Court of Michigan to these facts, and that body

immediately, of its own motion, recalled the case of Wilson vs. Hoffman, and reversed their decision. As a reversal of the Clute vs. Fisher case would have made no practical difference to the parties concerned, it was not recalled, but Judge Sherwood told me at the time that the decision in that case would not be followed by the court in its future rulings, and it has not, so far. In the recent case at Reeds Lake, near Grand Rapids, the court went squarely back on it.

Mr. Geisler.—The reason, I should say, that a riparian owner would continue beyond the meander line is, in all States in which the common rule is applied, that after the United States has once patented the land adjoining the water it has nothing more to patent, for the reason that it never reserves anything under the water, because if it should do so, it would make the titles unsafe and an adjoining owner would not know what his rights were.

The theory to be guided by, is to ascertain in the first place, whether you are regulated by any statute other than the common law, and if you are regulated by the Common Law, you will be safe in saying that in all waters, not tide waters, whether navigable or not, the owner owns to the the thread of the stream, for this point is well settled.

In one English case, the question came up a few years ago regarding a lake of some 13,000 acres. The contention was that the rule of the Common Law was that all rivers in which the tide ebbed and flowed were navigable, and others, non-navigable. They tried to take the position that that did not include lakes, but the highest courts in England have taken the position strongly, that the Crown of England does not own any soil under the water in lakes that were not "deep waters."

The rules of Common Law apply not only to rivers, but to lakes of all descriptions, and on that position, the law is applied to the Great Lakes; the only difference is that the public character of the water gives the state more control than over strictly private waters.

Mr. Courtright.—The idea, then, advanced by the Supreme Court, that possession gives title; these people have had possession of that for several years,—

Mr. Geisler (interrupting).—You mean by Adverse Possession. There is a rule that you cannot get adverse possession against the United States. You can get adverse possession against a private individual, if he has once bought the land, but not against the United States if the land has never been sold.

Mr. Hodgman.—I don't fully grasp the situation there. Of course if the Common Law rule holds good, the United States has parted with its title. Is it the riparian owners that have possession of the S. E. ¼ of 23, or someone else?

Mr. Courtright.—It is the riparian owners.

Mr. Hodgman—If the riparian owners have possession, they can keep it all right. The question is, how much they will get.

Mr. Courtright.—How will they divide it among themselves under the Common Law rule?

Mr. Geisler.—If you cannot apply any of the well-settled rules of survey, by running the lines perpendicular to the shore, you will have to have a partition suit and divide the area of the water in proportion to the frontage you have.

Now the case referring to Green Bay, I should say would be applicable to that. I have forgotten the title of the case, but it is cited in my paper.

Mr. Rogers.—I would like to ask Mr. Geisler a question. Supposing the Government owns a water route on a river like Saginaw river, and dock lines have been established along the river and approved by the United States Government, and supposing an individual wishes to build or put up a substantial building, clear out to the dock line; could anybody stop him?

Mr. Geisler.—To what extent is the river navigable?

Mr. Rogers.—It has been dredged out by the Government and is navigable for quite large vessels. Of course no person can build an inch beyond the dock line, but suppose he is willing to dispense with the dock, and use the land for a warehouse; could he do it?

Mr. Geisler.—Who established the line?

Mr. Rogers.—The United States Government; it was approved by the Secretary of War.

Mr. Geisler.—Yes, he can go to the last inch. The Government does not recognize dock lines established by cities, but where it establishes them itself, you can go to the last inch. Of course, many times, things of that nature would be governed by circumstances. While a rule strictly laid down might work all right in one case it might create injustice in another. A person would have to use his best judgment and common sense to know how far to extend the lines.

Mr. Skeels.—I am a little interested in another question. For instance. The City of Grand Rapids has bought Island No. 1 for a city market. A spot near the upper end of that island has been used as a dumping ground by the city. Now the material from this dumping ground has washed down to the head of that island, and in reality the area of that island is much greater than what was returned by the Government surveyor; would that properly be considered accretion to that island or must the City Government proceed on the ground and re-meander the island and establish, as far as possible, the old meander line and not go beyond it, or can they include all that part gained by the accretion?

Mr. Hodgman.—Can the city go on and make its own accretions or not?

Mr. Appleton.—That is done in Grand Rapids. If a man wants a piece of land along the river, he fills it up and occupies the bank.

Mr. Geisler.—You say this is an island in the centre of a stream?

Mr. Skeels.—It is an island in Grand River. The channel on the east side of the island proper has been dredged and used as a basin for some boats. They come up the river and turn in there and tie there, and it has been filled in from the mainland, across what was the upper part of this island, and made a highway from the main land around on to the head of the island, but it has been established I think, by decision of our courts, that that channel was there, and it has been located, but as it is now, it is connected with the main land, the island is, but although the island lies east of the body of the river, and the river is now on the west side of the island, yet at the time

it was meandered, there was a large channel on both sides; steamboats went up either side of the island.

Mr. Appleton.—Better pitch into the City of Grand Rapids for obstructing the river.

Mr. Geisler.—Has there been any dock lines established on the island?

Mr. Skeels.—I think so. We have done everything that anyone else has.

Mr. Geisler.—In answer to that question. The rule is that you are entitled only to those accretions that come gradually, but if that is a slow working accretion, helped along, perhaps, by the washing of the waters, it is hard to tell what position the court would take. I think, applying the rule strictly, they would not be entitled to any accretions, but what position the court would take in a case of that kind, it is a difficult matter to tell. I think you will find a great many authorities that would hold both ways, but there would be no question about it that you would not be entitled to the accretion if you dumped it all there in a week or a year, but if it was also the washings of the shore and the alluvial lands, it would raise a different question. These things would have to be taken into consideration and also the exact location.

Mr. Skeels.—There was quite an accretion there before the dump proper, got to the island.

Mr. Geisler.—It might be situated in such a way that the accretion would naturally form. This might cut a very important figure in deciding the case.

Mr. Skeels.—What I wanted to draw out was, where would the island leave off and the artificial land begin? The Common Council has authorized the City Engineer—well, it is sort of a double order or has two bearings. One was to find where the old meander line ran and the other is to determine the lines of the property they have purchased.

A. They can't do it.

Mr. Skeels.—The point to meander from is unfindable; we can guess at it as we do at many other things, but it is impossible from any data we have left to locate the point from which the meander commenced.

A. Then the best thing to do is to claim all you can, and let the other fellow tell you how much you can't have.

A Voice.—The best way is to let the man that they bought of give the lines.

Mr. Hodgman.—Get the lines as near right as you can and let someone prove them wrong if they can.

Mr. June.—That is a question which is referred largely to the judgment of the surveyor; Judge Cooley calls it the judicial functions of the surveyor, and if it depends on his judgment, what should his judgment be based upon, the reasons, or should he foresee the action of the court? His judgment is all right if the court don't dispute it.

Mr. Hodgman.—It is utterly impossible to foresee what the court will do.

M. Geisler.—The judgment should be based upon equity and sound common sense.

Mr. June.—But that common sense has got to be in line with the courts.

Mr. Wells.—My idea is to go ahead and make tracks for the courts to follow. I have been interested though, in some cases where we tried to make some rules for the court to follow, and they jumped clear over the fence.

Mr. Appleton.—I suppose all there is for a surveyor to do now is to find the old line, and if he can't do that, find it as near as he can.

Mr. Hodgman.—There is one thing about it. Not more than one case out of a hundred goes beyond the surveyor's decison. If the surveyor goes before his patrons and does his work thoroughly and honestly, and is willing to tell his reasons why, and they are plain and substantial justice, in ninety-nine cases out of a hundred his judgment will be accepted right there.

Mr. Geisler.—I can say this; if there is any trickery by a surveyor, the chances are it will be found out.

ELECTROLYSIS.

THOS. P. WHITTIER.

The profession of electrical engineering can be fitly compared with that of medicine. There is some fundamental knowledge in both, but it is largely empirical.

They remind me of the old gentleman, who, being very sick, had a consultation of physicians. Thinking they had not told him his real condition, he asked his old colored servant what he had heard them say. The reply was, that after considerable talk, they said, "the autopsy will tell." So it is with elecrical engineering; the autopsy tells.

On some points there is ignorance, real or assumed, for which there is no excuse; notably the damage to water, gas and sewer piping. This brings up the question: "Can anyone rightfully appropriate the property of others to his own use, to the detriment of the owner, without recourse, because the manner of the appropriation is not generally known?"

The business men of this city, as in all cities in which the earth is used as a return conductor for heavy electrical currents, have suffered materially from the destruction of their piping, and the city, as a whole, from the destruction of its water piping, saying nothing of the interruptions to private interests by these appropriations of the metal that they have placed in the ground.

It is a well known fact that electricity will, like other demonstrations of force, go where it can go the easiest, and that it is an utter impossibility to confine the current to one conductor when there is another open to it that will lessen the total resistance in the circuit, and any conductor offering a second path will reduce the total resistance, no matter what the second path's resistance may be.

One of the hobbies that electrical engineers have ridden, is, the increasing of the cross-section of the rail to carry back

the current in street railway service to the generating station. There was a period in electrical investigation in which they figured the earth as naught, as resistance. I remember some years ago, being with experts at Chicago, when this subject came up. At that period it was generally understood the earth was common property, and knew no metes and bounds as regards its use for private or corporative companies. I suggested the idea to them that I had been at work measuring earth resistance, when they pooh-hooed the idea and flashed their fundamental law upon me. I asked them if they remembered the experiment of the Western Union Company, in one of which was a large bicromate battery set up for the purpose of breaking a hole for the return current between Chicago and St. Paul. They said they remembered the fact, because it was quite a question whether there should not be another conductor sent to St. Paul to take back return current, and it would cost a good deal of money. I then asked them what was the necessity of so much potential or pressure, if it was not to overcome the resistance of the earth, when one of them, who had been long in telegraphic employ, agreeing, cited that they had brought one of the cables of the Atlantic coast out upon a ledge of slate, and that to get a good return, had to anchor an electrode some distance from the shore to establish the practical use of the earth return. In bringing up this question of earth resistance, we consider the earth not only as a conductor, but as a network of conductors; or in a comparative sense, using the human body as an example, with its blood circulative system already properly proportioned for the maintaining of life, and utilizing these venal and arterial channels for entirely outside work. Now, should we break down the walls of these channels, causing a lesion, this lesion would cost the life of the person or great sickness: and should this lesion take place in the brain, paralysis or apoplexy would ensue. We have not yet had any such extreme case, but should this use of our water system continue, and a fire such as we have had, occur, and such demands on our water system result, as we have had, paralysis would be a mild method of expressing the disaster caused by this appropriation by owners of heavy currents.

In street railway construction of the present day, we find an overhead conductor used to carry the current from the power station to the cars, thence back to the dynamo though the rails. In every electric system of this character there must be a complete circuit, or in other words, if you carry a given amount of current out over a conductor, there must be the same amount returning to the opposite pole of the source of current; hence there must be as much return to the dynamo through the rails as is taken out through the overhead trolley wire. As the rail is used as a conductor while imbedded in the earth, which is also a conductor, we must consider which is to do the greater part of the work of returning the current. By proper bonding of the rails, and by a system of return wires connected to the rails at short intervals, the resistance of the rails and return system is brought within reasonable bounds, and so long as the connections are perfect between wires and rails, the flow of current through the earth is comparatively small, but the continual pounding of the cars over the rail ends tend to loosen the joints, and the formation of an oxide of the metal very materially increases the resistance, while the earth resistance remains the same (subject to the variations caused by moisture). Thus the tendency of the current to take the path of least resistance or distribute itself among the conductors in the earth, shows that it may follow a system of piping to a point near the power house where the greatest quantity of electrolysis of metal is going on, because all the current must come there by whatever means it takes to return, and so our piping first gives out in that vicinity, though it is going on at all other points more or less, in proportion to the use of current. Direct current of any sort will cause the same result to metals imbedded in the earth. Supposing an electric light current becomes grounded in two places. There is a flow of electricity between these two points which tends to decompose conductors; as may be inferred, the street car rail is undergoing decomposition, but very slowly, as the current is not leaving at any one point, but evenly distributed throughout the entire length of both rails.

In crossing rivers on a drawbridge, the common practice is

to use an uninsulated wire for the return, laid on the river bottom. This gives a second path of comparatively low resistance, as the body of water is enormous as compared with the wire, which is usually of copper. Were the cross-section of the two conductors the same, there would practically no current flow through the water, as the specific resistance of copper is but .000,001,504 legal ohmes, as compared to 9,320 legal ohmes. The first measurements by Dr. Matthiessen, the second by Pouillet. The current would divide in this ratio (inversely), provided there was no work to be done in the decomposing of the water which would tend to raise the apparent resistance of that path, but when the relative size of the two conductors is considered, it will be seen that the only resistance of the water to be considered is that of contact with the wire.

Poor insulation of wires carrying heavy direct currents gives rise to leakage through the earth, but as a rule this is very slight, as any very heavy ground (as it is known in practice,) would or should be known by the dynamo tender shortly after its appearance. However, faults of this character may and do exist, to a small extent, without the knowledge of the attendant, and while the electrolysis from such source is small, it is present never the less, and if continued over an extended period of time, will be felt.

Is our water supply the only source of anxiety we may have? What if this degeneration of iron piping should eat through a large gas main and the pressure upon the pipe force a hole into the sewer and a mixture of the gas with air in the sewer be ignited, by a man attending to his duties of cleaning a catch basin, with a lamp or a lighted pipe? Are we not living over the crater of a volcano that is liable to carry us to the destruction of human life, which is far more dear than the destruction of property?

Every engineer knows the result on conductors of crystalization caused by carrying direct current. This applies to our bridges, which are in several instances upon this river being used by a return current which may give us an Astabula disaster.

Do the electrical engineers who advocate the bonding of rail, appreciate the fact that the use of a bond other than of the same material from which the rail is made, is simply increasing their resistance, for local action between different metals decomposes one and also creates secondary or counter electro-motive force, and while as an instance, men have been criticized for using iron wire as an excuse to comply with the laws created by city governments (and they were laid, not from the knowledge that they were better had they been larger), but because they were cheaper.

Taking it up as a question of secondary action or electrolysis of metal, they are forming oxides at the points where the current makes these jumps from rail to bond, and from bond to rail, all of which set up the opposing force of increased resistance, and necessitates an extra creation of horse power to overcome such resistance.

The doctrine of conservation of energy teaches us that no work can be performed without an expenditure of energy, hence it will be seen that in an electric circuit where the current is running cars or lights, in getting back to the dynamo is decomposing metal; the person or corporation supplying this current is paying for the electrolysis as well as for the operation of the motors or lights. The salt used for the reduction of snow and ice resistance on tracks and the surface grading of roads and pavements increases the ease with which the current is carried to our water, gas and sewer mains, and therefore should be discouraged as much as possible.

In electrical construction or engineering of any sort, the period is here, when men constructing work will necessarily have to insulate from outside influence, all metal placed in the ground, or advocate the use by corporations of their own conductors for return of current.

ELECTRIC STREET RAILWAY CONSTRUCTION FOR CITIES.

R. W. ROBERTS, CITY ENGINEER, OF SAGINAW, MICH.

The question of a permanent street car track is today annoying municipal public works officers and street railway managers, to the extent that it is requiring the exclusive attention and service of engineers. Prior to the early part of the year 1886, the surface street car roads of our cities were generally operated by animal power, some of the larger cities where cables or "Grip" cars were in use being exceptions; the service was conducted in small, light cars with a maximum weight when loaded of four tons, and an average of not to exceed two tons on a 6-foot wheel base. With these light rolling loads little attention and skill was required in constructing the road bed and track other than the service of an experienced trackman to properly line and surface the rails of the track, and such tracks would stand the service for years in an improved street, with little if any repairs and without damage to the street surface and subterranean property.

In February 1886, F. J. Sprague constructed and equipped the first electric trolley surface street railway in Richmond, Va., that was exclusively and successfully operated by electric motive power; this was the beginning of a new era in street railway service, and since that time over 4,500 miles of surface street railways have been equipped with electric motive power over which are operated about 7,000 electric cars. Until within the past three years electric surface street railways were somewhat experimental, but since that time the requisites for a successful electric street railway are practically agreed upon, while there are changes in the minute details at all times, the salient points are fixed. A large per cent. of the electric street railways of today are old horse car roads which adopted the new mode of propulsion. The electric equipment of a street car system,

cars, power station, trolley wires and poles were very expensive and as a general thing the capital of the promoters was all consumed before track construction commenced, resulting in operating the old horse car tracks which caused many disappointments; everything was too weak, motors had to be made stronger and heavier, more people were carried per car, the speed was greater, the stops and starts were quicker, and so it went on with every detail of construction until today rapid transit requirements in cities, for strength and durability of roadbed and rolling stock, are fully equal to steam railroad requirements, and in some respects exceed them. The ordinary electric motor street car, loaded, weighs 16 tons, and the most approved cars now in use on the rapid transit lines connecting suburban towns with the larger cities, weigh with load, 25 to 30 tons.

The track laid to carry these loads and keep its surface and alignment and be so rigid as not to vibrate sufficient to loosen the pavement along the rails, and that will continue so without repair for eight or ten years, is the track now desired both by street railway managers and municipal authorities. When the engineer is seeking information as to street railway track construction he is naturally directed to the experienced officers of our steam roads, but the conditions of maintenance are so different that the street railway must have a different construction A steam railroad track is under constant supervision of section men every day in the year, there is nothing in the way of tamping up a low joint or surfacing and lining the track every time, the track would be improved thereby. Steam railroad roadbeds are elevated either on embankments or in excavation above the surface water level so that the water drains off rapidly, the base of rail can be proportional to the heighth. The street railway cannot be repaired without first removing the surface of the pavement and foundation; and this cannot be done without interruption to travel, expense and damage to the street surface; the grade cannot be elevated above the surface water line, as it must be to the fixed street grade which should be below the grade of the abutting property. The rails cannot be the best proportioned and most

economical but must be suited to the kind of street surface or travel upon the street; the track must be on a rugged foundation with the least possible vibration.

There is a good deal of contention as to the best kind of rail head for street use. Three years ago the writer visited several of the progressive cities, seeking information from which to decide as to the best street rail, and found a variety of rail sections in nearly every city visited, so there seemed to be no unanimity of practice as to the kind of rail in use. Many of the older cities still adhere to the tram top girder rail, but the rail section being most laid at that time was the "T" rail section 6″ in height and the half and full grooved rail 6″ in height. The latter was found to be generally preferred by the city authorities though it is generally objected to by the street railway managers. The result of examinations at that time and of experience since, lead me to believe that the full groove rail will give better satisfaction under all conditions in the improved streets of our smaller cities where the pavements are wide, than any other rail section; aside from the "T" section it is the nearest center bearing; any kind of a pavement can be laid close to it and flush with the top surface of the rail; it affords no obstruction to the free use of the street by vehicles and it affords no tramway for the wheels of heavy loaded vehicles to track on and obstruct the free use of the street car track.

There is a great deal of trouble coming from the loosening of the paving material along the rails and over the ties of street car tracks, and all pavement covering the space occupied by a street car track foundation should be laid close, with interstices filled with paving pitch or grout, so as to make it impervious to water. Asphalt or McAdam cannot be successfully maintained along the rails of a street car track without a toothing of block pavement, of stone or brick, to prevent vibration of the paving material.

While I am unable to advise you how to lay the ideal street car track, I have seen so many poor ones and so few good ones that I will give my idea of how to lay a reasonably permanent and economical track. Sub-drain the roadbed with

drain tile laid directly under the track, with the trench filled with some coarse material, gravel or broken stone; this drain should be laid 3′ below the grade of the track. Upon the subgrade lay a foundation of hydraulic cement 6″ thick and 2′ wider than the length of ties. Whether this concrete foundation should extend in one sheet the entire length of the track or only 12 to 15″ in width, for the support of each tie must be determined by the amount and character of the traffic; of course the former is better, but I have obtained good results from the latter. The surface of the concrete base should be from 2 to 2½″ below the bottom of ties; this space is required for ballast and cushion, and it should be uniform, as a variation of the ballast and cushion permits unequal settlement and too much vibration to the rail. Upon this foundation lay white oak ties 2 ft. centers with a full groove rail 6″ high, weighing not less than 60 lbs. per linear yard, without cross rods or flange braces, with long splice bar fish plates that will fit closely against the flange of the rail. These small things are mentioned as there should be nothing projecting from the rail that would prevent laying the pavement close to it, if there is, just so sure will the paving get loose and your pavement be seriously damaged. I recently saw 2½ miles of apparently splendid track laid with heavy 70 lb T rail in a new pavement, pavement and track having been down less than two years, and 70 per cent. of the pavement between the rails and for one foot on either side, was entirely out, and simply because these small matters were not attended to. Now to complete the track construction, the ballast should be fine dirty gravel that will pack, and after the ballasting is done and the track lined and re-surfaced it should be operated sufficient to detect any poor tamping and ballasting, then re-surfaced and lined and the whole space between ties concreted and very thoroughly tamped on top of ties when the space is ready for the paving surface, which should be made impervious to water and kept so.

The question of properly constructing, in connection with an electric street railway track, a sufficient and permanent return circuit, or in other words to prevent electrolysis, would require a paper in itself of considerable length to describe the

various methods used, and as this question is to be discussed and considered by experts I will attempt nothing further than to explain how and what I did to prevent electrolysis, and I assure you it was a bad case, on about a mile of double track road in this city. When the track was equipped for an electric road in 1888–9, the rail used was a tram rail, weighing about 26 lbs. to the linear yard, laid on a longitudinal stringer. This was bonded at every joint with a No. 6 copper wire and one No. 6 supplementary wire laid between the rails of each track. After the road had been in operation about two years frequent defective water and gas service pipes were found, causing the water and gas companies much annoyance. This continued for about two years with frequent leakages in service pipes before the cause was fully agreed upon. Then several remedies were proposed and tried, but all, I think without any effect. At this time the street pavement and the track in it required re-construction and the matter was taken up with a view of making it a return circuit, which was done by bonding each joint of the 60 lb. rail with two and three No. 00 copper wire, with a supplementary wire of one No. 0 and No. 00 wires between each rail connecting with the rail bonds and cross-connecting every 90′. The supplementary wire was put in voluntarily by the street railway company. I believe sufficient rail bonds will answer every purpose, as a 60 lb. rail is electrically equivalent in carrying capacity to one square inch of copper if the capacity at the rail joints bonds is so as to make its capacity continuous; with a double track we have a return circuit equivalent to 4 square inches of copper. From this return circuit, rails and supplementary wires were connected with 8 No. 00 wires carried over head and connected directly to the dynamo at the power station. Further than this as the earth will, under some conditions, take some of the return current no matter how great the return circuit may be, any part of the current that takes the ground in preference to the return circuit provided for it, will naturally find its way onto the underground pipes, and while it may travel upon the pipes for miles without doing any damage, when it gets near the power station it will go back to the return circuit and thus

cause electrolysis of the underground pipes where it leaves them for the track and return circuit. To prevent this and take away any possible current that might be flowing over the underground pipes, I put up an overhead return feeder for about one-half mile each side of the power station and every 300 or 400 feet connected it to the underground mains by tapping the same with a brass plug screwed into the pipe and the wire soldered onto it. In this way any current flowing along the underground pipes will take the path of least resistance which is the overhead wire, instead of going from the service pipe through the ground to the rail. I have since examined one pipe in the center of the danger district and there was no perceptible effect of a current passing from it or over it.

The President.—These two papers are now before you for discussion. Perhaps Mr. Ames can give us something of interest as to what effects you have suffered from electrolysis in Grand Rapids.

Mr. Ames.—I have not heard any complaints in regard to it. The Street Railway Company asked permission to connect their wires with the water pipes, when they first began to put in the electric roads, and the permission was denied them; I have heard of nothing serious occurring from electrolysis.

Mr. Sears.—How does your system compare with that outlined by Mr. Roberts?

Mr. Ames.—The ties are laid on the dirt, on the earth foundation. We don't put any concrete underneath. The construction of the car tracks is entirely in the hands of the company. The city has nothing to do with it. That is, we don't do the work. But in laying pavements, we concrete all around between the tracks, six inches deep. The track sometimes settles—in fact it almost always does; in many of our tracks, you can count the ties as you pass over the surface of the street.

Mr. Granville.—What is the nature of the soil?

Mr. Ames.—I think we have everything on the face of the earth, though it is principally a gravelly soil.

Mr. Granville.—It occurred to me, from what Mr. Ames said, that they had no trouble with electrolysis, that perhaps some of this trouble might be accounted for by the nature of the soil upon which we build these roads. In this city, you know, it is nearly all clay soil, and we have a great deal of trouble, and I presume that fact could be demonstrated by finding whether they have the same trouble in other places where the nature of the soil is the same as ours. In Grand Rapids the soil is different—perhaps they don't have that trouble in places with that kind of gravelly soil.

Mr. Ames.—I might say that there is a small amount of electrolysis going on—I have noticed some small pieces of pipe in which there was electrolysis taking place, but we have had no serious breaks in the mains, and therefore no very careful investigation. Of course we do not know to what extent the pipes may be injured.

Q.—I would like to ask Mr. Whittier the difference between the two soils.

Mr. Whittier.—There is some difference, but it is very slight.

Mr. Roberts.—Electrolysis is by no means confined to the Saginaw Valley or Saginaw. It was one of probably fifty places where electrolysis started about the same time. In Milwaukee they had substantially the same trouble that we have here, except that it covered a larger area and was not as severe, but it damaged their pipes. The remedy suggested and adopted by Mr. Benzenburg was to connect the water mains with the track, with galvanized iron wire—⅜ inch wire—wrapped around the pipe and I understood from him that there was no special care taken to get a connection of the metals—no scraping of the pipe or soldering the wire on the pipe, but they made these connections so as to equalize the potential—keep it the same on the rail as on the pipe.

The trouble here and in other places, is in the current passing down through a motor car, through the wheels to the earth. If the rail is an ample conductor to take it back, it will take it pretty much, but there will be some leakage, and that will spread out onto the pipes, and may cut across lots. Our

power station is located on Washington Avenue, about a half mile south, and the other lines run out east. I know that the current is traveling across on the pipes, following the blocks around and across, near the power station. When it comes there, it does not, as at first supposed, cut across lots to the power house, but it follows in from the main on the service pipes, to a point immediately under the rail, and there it goes to the rail, and at that point is where electrolysis takes place.

Mr. Sears.—I like Mr. Robert's paper; it is very concise and well stated throughout, and his suggestions are very good as to the construction of street railway track. There are one or two things I would like to ask him. After putting in the foundation, in proper form to eliminate the vibrations—how do you protect your tracks on either side? I don't think your method is quite full enough.

Mr. Roberts.—No, we have not complete control of it, but it is about as good as we can get where we haven't it all to say. It is the same with us as with Mr. Ames. The Common Council gives the Street Railway Companies ordinances without much regard to the future, except that they give them for about the natural lifetime of a man, thirty years, and the details of constructing and operating the same, and taking care of the return current and all that sort of thing, are lost sight of. I never saw in an ordinance, a mention of a return current until it was put in the ordinance here, less than a year ago.

We use here a concrete foundation, 12 inches in width, under the tie. It would be better to get a continuous sheet of concrete, but we have been able to get the 12 inches, and it is doubtful if we could have gotten the continuous sheet. In laying the rail, it should be independent of the tie except as it is spiked onto it. The braces that are usually put on, the cross rods sometimes put in, and the fish plates that project outside of the ball of the rail, all of these, it is hard to fit the paving material around these projections, and as Mr. Ames said of Grand Rapids, you can count these projections on the surface of the pavement.

Mr. Sears.—About a year ago I was talking with Mr. Hawks on this topic—he is manager of the Street Rail-

way system in Detroit. Their soil is quite a good deal like ours, and he was at that time running a system of levels, to determine whether the pavement was going up or the road down. He said it was more difficult to keep that in surface than a road carrying engines. He said we did not use ballast enough, but he used the system of ballast described. They dig a little trench for each tie, eight to twelve inches wide, and it is a concrete tie, laid under the real tie, covered with the cushion of ballast. These little cuts, undrained, receive more or less water and in the winter time that is pumping up and down.

Right here I want to call Mr. Roberts' attention to the fact that on two blocks on Genessee street, they have placed a foundation such as described Last spring there was a hollow about one-half foot deep in the center of the street; from this vibration there are more or less cracks, and the water finds its way into pools, and the frost will cause a change in the surface.

Now it seems to me that on clay particularly, we should put a layer of ballast or gravel under this concrete—that is, form a sub-drainage, connected with the sub-drainage he has described; the sheet of concrete should be continuous, and the city should compel the same. I would like to ask Mr. Whittier whether he considers Mr. Roberts' precautions against the return current, ample?

Mr. Whittier.—No sir, I don't. We have had five or six years to develop diseases in our piping that have been sufficiently serious to require marked repair. That same action has been going on all over the city and in time will break down all the pipes that come within the range of the carrying back of the current of the power house, and the only remedy I can see is the one which Mr. Roberts suggested, in his copper return, in the air. The expenditure of a small amount of money by the street car people, as compared to their present construction, (for they have their poles and cross wires in position) would be sufficient to put up a double trolley wire system, keep the thing above ground and let the people have their own property unmolested.

Mr. Sears.—I would like to call upon Mr. Brown, who has paid a good deal of attention to the construction of tracks.

Mr. Brown.—I know nothing about electricity. On the F. & P. M., my experience goes to show that we must have some drainage. We must get the water off the track as quickly as possible, and it is necessary to have a reasonable amount of ballast in order to do that.

. On three different occasions since 1867, the track between here and Bay City has been washed away for four or five miles. The road bed was originally clay loam—blue clay—and in rebuilding the road, they would not give us time to put in sufficient ballast, and wherever it would wash out, you would find a hole perhaps eight inches deep; the result was that whenever there was a rainy time, we had a wet track, the mud would fly, and the only way to overcome it, is to get ballast enough to prevent this clay from rising up between the ties and have a uniform surface. Any trench that pretends to hold water under the rail is going to make trouble; that is why I think the system of trenches on the street car track is wrong. I think as Mr. Sears says, that the concrete should be made continuous, and in addition to the sub-drainage, there should be some sort of ballast underneath, and then if possible, make the surface impervious. With a dry surface underneath these ties, I don't see why the track should not remain as good as in the first place.

Mr. Appleton.—I think one of the greatest troubles about this is that when the charter was granted to the railways, very little was known of electricity. They were given a charter for thirty years, and agreed to pave inside the track, with the same kind of material employed by the city outside the track.

Now when the trolley car supersedes the mule and horse car, and heavier cars are used, there is trouble. We cannot get the street car company to do anything about putting down concrete under the pavement, nor they won't pave, and the whole matter with us is now in the courts. That new street that was paved last summer, we have a curbing of about a foot outside the rails; they are light rails—altogether too light. First of all there was a strap rail, now they have a T rail, and

there is nothing under the ties but dirt and the track is simply abominable. We expect to put in something like a mile of brick pavement, and I hope the matter now in the courts will be decided so that we can make them do something. It is a continual struggle there, to get the Street Car Company to pave, although they have agreed to do it—it is in their charter.

Mr. Sears.—Wouldn't sub-drainage, and a thorough coat of ballast, well applied, without the concrete, do there?

Mr. Appleton.—I have no doubt of it. They have no drain, no ballast, and while the city has two rows to run on each side of the track, it has only a single track in most places, but there is no drainage or anything else.

Mr. Hodgman.—Vote for Pingree.

Mr. Roberts.—I heartily agree with Mr. Sears and Mr. Brown in regard to their steam road track; of course they are at it all the while. If you have a foot of ballast, it is constantly settling, and you are constantly repairing it. I don't believe you can maintain the surface of the pavement over the foundation of a street car track, laid on ballast, no matter how well you drain it or how much ballast you put under it.

Mr. Sears.—You can keep the water out though.

Mr. Roberts.—Take the ties that are seven feet long, laid with three to four inch tiled drain, three feet below, filled with gravel or sand, which affords sub-drainage good enough; that takes the water away.

Mr. Appleton.—It would take a good deal of work and material to do that.

Mr. Roberts.—Now then, suppose we have 12 to 15 inches in width of concrete under the tie, I admit it is not all we would like, and while it will answer for some streets, there is some traffic in this city where it ought to be better, but it is more than a concrete tie, Mr. Sears. Your tie would be an independent piece, put in there, but the excavation is made and the concrete is tamped in there, it has support on the sides that a tie could not have, unless you tamped the tie on the sides, and then it would not adhere as concrete would.

Mr. Brown speaks of the tie binding and making a bed, and between the ties, the clay coming up. Now that is just

the case in the street car tracks, but with a concrete bed six inches thick between the ties, 18 inches in width, doesn't it help to hold that clay down? And if it helps to hold the clay down, it helps to keep the foundation of the tie up. The continuous sheet is better, but of course we must take what we can get. As regards the tracks in Detroit, I think Mr. Sears is mistaken about the concrete trench.

Mr. Sears.—That was a portion of the track when they first commenced.

Mr. Roberts.—On Woodward Avenue the track is laid on a continuous sheet of concrete. A little past the City Hall, on Woodward Avenue to Jefferson, they excavated, and put in from four to six inches of fine gravel under the double track foundation. They did this eighteen feet in width. They put on there a cobble stone pavement, laid and tamped it. They put on top of that a six inch bed of concrete. Over that they laid six inch ties and concreted between the ties and above the ties three inches. They had there in the neighborhood of twenty inches of foundation with lots of ballast, and twice a year, just as regularly as they could get the asphalt companies there, they repaired the asphalt surface, along the rails of the track. That is necessary owing to the vibration; the best construction yet, if it were practicable, would be to lay your tie in concrete, but I don't believe that that would be practicable, do you, Mr. Brown? That is, you couldn't get your surface and your alignment with any reasonable expense.

Mr. Brown.—You would have to get your alignment on the surface before you put the concrete on, if you did

Mr. Roberts.—It could be done, but it would be a great deal of expense, would it not? That would be better, but as that I think is impracticable, then take as little ballast as you can get along with, and surface up your ties; that ballast, with the concrete placed in between the ties, is cased in between the tie and the concrete and is just as good then, as the concrete. It cannot get out, either down, on the side or up.

Mr. Brown.—That is the construction they have in Detroit now, is it not?

A.—No sir, not that I am aware of.

Mr. ——— Out on Jefferson Avenue, where that electric motor was used, I noticed that the ties were bedded solidly into the concrete, and the surfacing and aligning was done before the concrete was put in. The ties were blocked up with solid matter before the concrete was put in, and I should judge from four to six inches of concrete was used.

Mr. Duncan is a resident of that city, and probably has noticed the construction.

Mr. Duncan.—I noticed when they were laying the pavement, and welding the rails, but I understood it was a continuous sheet of concrete with a thin coat of ballast.

Mr. Roberts.—Our Secretary has referred to Mayor Pingree. I think the condition of the street car tracks in Detroit, their bad condition, and the thousands of dollars that have been wasted by destroying pavements—(the President of the Board of Public Works informed me that the repairs on Jefferson Avenue amounted in two years to $67,000, caused by defective street car track construction) I think that they can pretty much be laid to Pingree's door. About the first thing he did was to require Mr. Hawks to cut the ties off close to the rails. You remember that, Mr. Sears—they said they had a shoemaker for a mayor and he was telling them how to build street railway tracks—and that has been the case all the way through, and I don't believe we want any Pingreeism in making our ordinances for street car tracks.

I think it would be a proper thing for this society to appoint a committee to take up the main features for street railway ordinances. It is needed now probably more than ever before. Every little town is trying to get an electrical street railroad, and as long as bonds can be sold and money raised as it can now, they will get them, because they are building them to bond them rather than to operate them, and these little towns could be protected if there was something they could refer to, and if every engineer in this society had something substantial laid down, that he could advise putting into an ordinance, it would help every engineer that hereafter does work in connection with street railways and every citizen of the villages and cities of Michigan.

Mr. Skeels.—How long has this system that you speak of, of concrete tie under the rail, been in use here?

A.—Two years.

Q.—What is the practical result of it, with comparison to other constructions?

A.—Well, I think this is about the first; Detroit put in concrete under ties a year or two before that, and it has done pretty well. There are two places here in four blocks of brick pavement—two places where the concrete weakened and the brick separated—but these are the only defects that have developed so far, sufficient to raise the pavements.

Mr. Appleton—Is that over six inches of good, well put in concrete, where the ties came up?

Mr. Roberts.—Understand, there are two ties in this distance of 1,400 feet of track. That would occur by not tamping the ballast under the ties.

Mr. Sears.—This foundation that Mr. Hawks put in on Woodward Ave. has been placed since I had this conversation with him. That reveals some points in regard to vibration. I want to ask whether, if after all, this concrete tie, with the cushions of earth between, isn't the best to prevent vibration; to deaden it? I believe that a good layer of gravel, Bad Axe gravel, thoroughly sub-drained, is better than your concrete.

Mr. Appleton.—It don't answer with us at all. I would rather take six inches of good concrete, well rammed, well made, well proportioned, and about two inches of cushion on it, and take my chances on keeping the ties all right. I think that is Mr. Roberts' idea.

Mr. Roberts.—Yes, that is my plan.

Mr. Sears.—In this connected sheet of concrete, wouldn't the vibration be greater than if it were cut in two at intervals?

Mr. Appleton.—I think that sub-draining, putting in good drainage is a very important thing.

Mr. Brown.—In regard to the ties working loose; isn't that likely to occur from careless workmen putting in this concrete? I observed some work this summer, where ties were being put in, that in some places the concrete was so high that it didn't require any ballast; in fact, it needed rounding off. In other

places, it needed perhaps two or three inches of cushion. It should be uniform, not half an inch in one place and three inches in another.

Mr. Roberts.—That is a question on which I laid some stress, in my paper.

Mr. Brown.—I did not hear the paper.

Col. Muencher.—A good many of the street pavements in Grand Rapids were laid on gravel. Probably some still remain, and there may be street railway tracks laid on them. I would like to ask Mr. Ames if he has observed how the tracks operate that are laid on these pavements, or if there are any left?

Mr. Ames.—Grandville Avenue, about a mile long, which was paved two or three years ago, was paved on gravel. The street railway track has the same kind of foundation, and the ties are quite as perceptible on that pavement as on the others. The track is in the best condition where we have concrete across the street. In some places, the Railway Company was allowed to put in broken stone, and the spaces between were filled as well as they could be, with the sand. The sand has settled, or the broken stone, and has left those pavements in particularly bad shape, and since then the Board of Public Works has insisted on putting concrete entirely across the street, and those are in better condition. The pavements have to be torn up around the joints frequently, and then when it is put back, it is never as good as on the start.

While I am on my feet, I might say that the remedy for the street car construction, I think, and for the electrolysis, is for the city to own everything that goes into the street. Let the street railway companies do the operating, but let the city own the gas pipes, water pipes and railway tracks. Mr. Elder, do you experience any trouble in Kalamazoo, with electrolysis?

Mr. Elder.—We have not had much trouble with electrolysis, as I know of, but the East Main Street pavement, that a year ago last fall was laid on gravel—sand and gravel—with the track laid on three inches of concrete, has not been at all satisfactory. The tracks are the roughest riding in town.

The President.—Col. Muencher, have you noticed any bad effects from electrolysis, in Manistee?

Col. Muencher.—No sir. Our street railway there has only been in operation two years, and we have not seen anything of the sort yet. There is no telling how soon we may. Our soil there, where the railroad is laid, is altogether sand, very deep, and it is possible that may have some little influence. Our pavements are all block pavements, laid on sand, and wherever the street railway tracks are, they are pretty bad, though they are not much better anywhere else.

Mr. Elder.—There is no settling of pavements at all, where they are laid on sand, but where there are tracks, they are in pretty bad shape with us.

Mr. Roberts.—I don't care to monopolize the time in talking on this question, but I think Mr. Whittier could tell us a great deal more, if he would just move his chair up there near the President, or stand up there, and talk in a general way. We could get a great deal of information.

When the street railroads were first equipped with electricity, I believe that the men who had brains enough to invent the system, did as well as they could in providing for the return circuit—it wasn't questioned at the time, was it Mr. Whittier?

Mr. Whittier.—Yes sir.

Mr. Roberts.—I never heard it questioned at that time.

Mr. Whittier.—As to the use of the earth for the return circuit, you mean?

Mr. Roberts.—Yes.

Mr. Whittier.—No, that is something that has come up since, especially the question of earth resistances,—getting away from the old theory that the earth was so large that it offered no resistance—so that this No. 6 wire that was used for binding and supplementary wiring was considered ample. It was put in there as a part of the equipment; they didn't consider that it had much use. The first road built I believe in this part of the country, was down at Port Huron, and while they constructed on an old horse railroad iron, strap rail, they placed under the joints a thin piece of metal to make connection between the rails. That was the first road I believe, outside of the Canadian one at London, which I think was the

first railroad on this continent. Next to that is the Port Huron development, and they recognized the necessity of lowering the resistance, and the autopsy proved that it was necessary. We are still laboring under a number of conclusions I think, that would be proven beyond any doubt to be specious, but which we have accepted as theories simply because no better can be advanced.

Col. Muencher.—I would like to ask Mr. Whittier if he can give us any idea as to the extra expense of equipping a road with sufficient return wire, dispensing with these bonds and everything else connected with the rail.

Mr. Whittier.—I never made any figures on that, but my idea of the matter is that the cost of any piece of machinery is not in the first cost—it is maintaining and keeping it up, and if, at the end of the year, the accounts have been kept accurately, I believe that the reduction of horse power and the replacing of loosened joints, and the diseases that come from bonded rails, if figured against an overhead trolley wire, that the companies would be largely remunerated in the change by these things for the first cost of the wire. But I believe that the reason why this has not been adopted is that some clever Yankee conceived all this some years ago and put a patent on this return trolley wire for carrying back the current, and the systems now in use, being largely hawks, preying upon what they can, have not adopted it. Take the construction of the railroad in this city as an engineering job. It was the laughing stock of engineers. They came here and took a little light rail that was light enough for a poor horse service, and the wires—well if they had been spiders and stuck their wires across the street with glue, they couldn't have been much poorer. Such a plan is short sighted; in the cost of maintenance, they have spent two-thirds enough more on this road as it is, than to have gone on and put in a decent construction in the beginning. But they came here with the idea of selling out the stock, and the result is what we have got. We must do the best we can with it.

Col. Muencher.—Every engineer knows it is possible to build a plant substantially in the first place, but I wish to draw

out the fact that, in the long run, a company would save money by putting up a return wire in the first place; that does away with electrolysis and the repairing of bonds, and a vast amount of maintenance work that otherwise cannot be dispensed with. As the knowledge of this electrolysis becomes general, these railroads will have to pay for the damage done, unless as in Grand Rapids, where they were cunning enough to foresee and ask for the privilege of connecting their system with the pipe, and in that case they would be using the water works system as a conductor, which, in the manner in which it is used, would not materially hurt it, because it would be simply used for carrying the current, and no intervening resistances would cause breaking down of the pipes.

Mr. Whittier.—If they were to connect the pipe at the power house, they would have to follow it through with a systematic measurement and a mapping of the water, gas and sewer mains, from a resistance basis, to find the short resistances over which the current would flow. The damage done is in the movement of the current from one system of piping to another. There you are decomposing the metal, so, should the city utilize a series of taps on their mains and make good connections and maintain them,—and that is a hard thing to do,—it opens a law point for any form of union that I have yet seen, unless it has been this electric welding and binding of rails, which makes the two materials a part of each other without increased resistance,—will break down in time. It opens a seam in the rail, and each coupling has an action of its own, laying aside the secondary action of the heavy current.

The President.—Mr. Whittier, I unders and that in Europe, in several cities, they are using, successfully storage batteries on street railways. Now, I would like to ask you as to that, and if the practice in our country is behind the times as compared with theirs?

Mr. Whittier.—The use of the storage battery is largely based on the source from which you can draw money to pay for the expense of running it. It is a question of dollars and cents. Every time you convert one type of force into another you have left something behind. It is like the man who tried

to carry molasses in a series of ten pails—he kept changing from one to another, and when he reached his destination he did not have nearly as much molasses as when he started. Every conversion of electricity makes a loss of from nine to twenty per cent. of the whole. Suppose you have 100 H. P.; turn that power over on a dynamo and you have lost 9% of the actual power, even with the best forms of dynamo known to-day, not speaking of the difference between electrical horse power and actual horse power. Then we turn that over a system of wires into a motor—there is another conversion and another loss, so that during the changes from the initial point to the point of work, there is only about 41 H. P. out of the 100 utilized. Now, in having a storage battery, which is another type of convertor—another molasses pail—you have still less horse power than was originally created. In cities, where the houses are 10, 15, 25 feet fronts and six to ten stories high, instead of, as in our country, where they are 60, 90, 120 feet apart, and only one or two stories high, you can draw people enough to maintain a secondary or storage battery. It is simply a question of dollars and cents.

The President.—The use of that, however, would entirely obviate the evils of electrolysis, would it not?

A. It would be independent of overhead trolley wires.

Mr. Roberts.—I think there should be a distinction made here between the return circuit of the double trolley system that Mr. Whittier speaks of, and the other. You are referring to the double trolley system entirely. I think Col. Muencher has in mind a return feeder.

Col. Muencher.—I am not sufficiently acquainted with the terms to know what you would call it. What I mean is a wire carrying back the currents to the power house without the intervention of the rails.

Mr. Roberts.—That is a double trolley system. You take it off or put it on to the circuit; put it on to the return just as you take it off. That is maintained parallel and close to the trolley wire; we don't want to add any more wires to our streets. Another trolley means stronger supports, closer together, a

third more guy wires at every intersection. This can be conducted as well on a feeder along the poles, can't it?

Mr. Whittier.—No, you have got to reach it with the trolley.

Mr. Roberts.—Suppose you reach it through an insulated wire, connecting your wire at every hundred feet with your rail?

Mr. Whittier.—If you can maintain a good connection with your rail by the use of two different metals, or can run out from your iron rail, an electrically welded body of cross-section sufficient to carry it, it would be all right; the resistance of iron is much higher than that of copper. It takes a piece six times as big to carry the same current.

Mr. Roberts.—Now, then, we are speaking of a track laid on a good foundation. You are thinking of an old track where the bonds were broken about once in every thirty days. I noticed recently that Edison has compounded an alloy that can be used with perfect safety for a rail bond without this oxidization at the joint. But, allowing that there is no metal suitable for a rail joint bond, if we could connect three rails, we could probably weld three or four rails, and connect each one of these with an overhead feeder to be strung along on poles, and I think you would be just as safe as you would with your double trolley system.

Mr. Whittier.—Yes, but it would cost more; you must consider the company a little bit. You can not, simply because you have the power, say, "You have got to do it our way." In construction, it would be cheapest for the company to put the wires within reasonable distance of each other, and use one extra trolley pole in place of carrying all this wire from the track to the side wire—the same cross section, because it has to do the work of carrying the current at the side of the street, and while it is necessary probably to put in a few more supports, it would not increase the number of wires materially in a mile of double trolley system. I don't know what the proportion is.

It would be adding one more trolley wire and no more supporting wires, simply increasing the size of the cross wires, for the reason that you can stretch a wire between poles with about the same quantity of sag, in any number. It is a question

of sag, and how it will stand the distance between the poles, rather than of the amount of support. You might increase the number of cross wires a little bit, but I don't know as that would be necessary. There is more power in the wire as used than is necessary to maintain that little weight.

Q. Should not the return trolley wire be larger than the out going wire?

A. Practically, less. In carrying out your idea, you must keep watch of your dynamo tender to see that he don't ground one side of the dynamo; should three or four of these feeder connections in the return break down, and a spot in the track increase the resistance, he would try and help himself out of that place until he could fix it, and it would not be long before there would be a great deal of that. It is a temptation to use a makeshift when a railroad system is dependent on the use of its power.

The President.—Mr. Whittier, in the use of this return trolley, or motor trolley wire, for the return of circuit, is it necessary to have a contact between that and the dynamo the same as I understand is now effected through the rail? In other words, would you have to have two trolleys?

Mr. Whittier.—Yes, one to take off and the other to put back—to keep up the circuit through the motor.

Q. Then you couldn't, in case of parallel tracks, return the circuit on one of the wires?

A. You mean the switching?

Q. No, suppose you have parallel tracks and a trolley, with single trolley wire for each one. Could there be an arrangement of trolleys effected so that the entire circuit could be carried in those two wires?

A No, I don't think so. When two cars passed each other, it would be necessary for the operators of the cars to shift their trolleys, one over the other; it may be that some Yankee will fix up some scheme to shift them by each other, but it would necessitate their reaching off at an angle from the car with their trolley, and in rapid transit there is not time for the shifting of trolleys.

Q. Then so far as the general knowledge on this subject

goes, if the return circuit is taken from the earth, it necessitates the double wiring?

A. Yes, more than double wiring. You would have to put all these feeders into the return wire, from the rails, say at every ninety feet, as was suggested.

Mr. Roberts.—That is for a return feeder. I believe the President was speaking of the double trolley system—that is, two trolleys and two trolley poles. The point I make against more wire is because in every city the clamor now is, to get the wires under ground. In Detroit they are putting them under ground; it is being considered here.

The return feeder, I believe, should be larger than the trolley wire which takes the current out; as I understand it, it goes out under force and comes back without any force. For instance, you will receive a certain amount of water through an inch pipe that is tapped to our water mains and pumped under heavy pressure. You open your faucet and let the water flow, and you must have a larger pipe than one inch in diameter for it. That, as I understand, is a parallel case. The current goes out with so many amperes—so much force behind it; it comes back without force. It must have a larger path and a larger wire.

Q. Won't the dynamo draw it back with the same force?

Mr. Whittier.—The quantity of current remains continuous. Mr. Roberts is right, that any electrical construction necessitates the maintenance of the cross section of the wire sufficient to hold resistance within reasonable bounds, and in carrying out two trolley wires from the station, the ends nearest the station would be the largest, for at the extreme end there would probably be but one car at a time; it would not require the same quantity of copper to carry the current for the propelling of one car without material dropping of potential; that is, when changing the pressure, as you get nearer where most of the work is done, you require greater cross section to carry your current. The taper should come from the station in both cases.

Mr. Ames.—I wanted to ask it the city owned the railroad tracks and the water pipes and the gas mains, and as electroly-

sis can only take place where the current leaves the ground or goes to the main, that is where the path is broken; if the path is made of ample size, sufficient capacity, why isn't it better to use these things and use them freely? At the power house you could construct a sufficient chamber underneath the street, through which all these pipes would pass, and free access could be given to it, and it would not be a large expense to construct a number of these places along the street, and you could use these things freely.

A. The disease would still remain because you are unable to maintain good connection between your water system and electric system, and the continual changing of water piping would necessitate a continual measuring of resistances and a changing to the lowest points for distribution of the current. You would have to keep after it all the while to know what pipes were being used. It would necessitate not only considerable labor, but skilled labor. A man who can not only make the instruments for measurement, but who was a fair draughtsman, and who understood the thing, would be needed to keep it in condition. Even then there would probably be a good many diseases which would creep in. A poor piece of piping would develop in itself some trouble, and reduce or increase the resistance, which would mean continual watching.

Mr. Ames.—I don't mean to depend on that entirely, but to use that after the construction of the road. There are certainly strong objections to putting in more wires in our streets. We want to get out what we have, but after making the road and the bonds in the best possible manner, why wouldn't it be a safety to the pipes to connect those, too.

Mr. Whittier.—If you take up that subject, it runs into the possibility of the city owning a conduit for the carrying of wires, and charging a rental to the private corporations. I don't believe in a city entering into any line of business which anyone else can do, as long as it does not infringe on personal rights. You open up a large question when you ask the city to do any type of business for the city.

Mr. Ames.—The matter of street railway tracks is as much a matter of public interest as pavements. No private company

pretends to make the pavements. The city must build and maintain them. The maintenance of a street railway track is as much a matter of necessity as water, and gas and electric lights are going that same way. I see no reason why the city should not own everything that goes into the streets. Leave the operation to a private company.

Mr. Reed.—According to the amount of power expended in the plant, does the electric light power have the same effect of electrolysis that the street railway does?

Mr. Whittier.—With but few exceptions in the history of electric lighting here, no engineers who have laid out electric lighting stations used an earth return, only in case of poverty where they did not have the money to buy the wire. They soon got out of it because it cost money to add such enormous resistance to their circuits as compared with the number of lights they were able to show. Where one side of a line is grounded, the possibility of killing people with high potential currents is very largely increased when used in the ground. The man simply touching the outgoing wire that carries the current to the lamp, or in trimming the lamp, may make a short circuit, and he is gone; as has often been the case. I think there are some three or four hundred people now on record as having lost their lives in that way.

I don't believe in unnecessarily persecuting corporations who own franchises, but where there is an evil existing, there ought to be something done in the legislative way. As I understand now, the various electric companies, whether intentionally or not, appropriate the property of others and with great damage to them, in order to effect a saving. As far as I am aware, in every state in this Union, there are statutory laws to restrain the running at large of vicious animals, which make a great deal of noise and give signs of their coming. People affected with contagious diseases are quarantined for the good of the public. Now, then, if there is a stray force running through the cities which gives no warning and is liable to cost the loss of life and destruction of property, it seems to me it would be a very good subject for our legislatures or city councils to take action upon, and effect a good deal of justice.

Mr. Duncan.—I would like to have a word on the subject that has been discussed. In the first place, I would like to ask Mr. Whittier about the conductivity of concrete, compared with earth?

Mr. Whittier.—I never made such a measurement, and I don't believe there is any data to be found, outside of the data of electrical engineering companies. It is a thing that could be ascertained very readily.

Q. Would you imagine there was very much difference?

A. Oh, there is some difference, yes. There would be a marked difference between the earth and the concrete, but both carrying moisture, it would not be so marked as would be supposed at first thought.

Q. Then in regard to the preparation of the street and the building of railroads for electrical transportation?

A. This has been going on in Detroit in perhaps a hundred streets in the past year. I have not followed the subject up closely, but I have had a good chance to observe different methods, and it seems to me that the up-to-date method, the best, is the one employed on Griswold Street, in which a gravel ballast was used, and on top of that a course of concrete; on top of this, iron ties were employed, and the concrete tamped under these; the rails laid on this, and then the concrete filled in up to the necessary height to meet the pavement. It seems to me that by this method of using iron ties, and fastening the rails to them securely by bolting, that some of the objections can be done away with, that have been spoken of, chiefly the one about the rails vibrating, and so tending to destroy the pavement. By imbedding the tie in the concrete it forms a solid mass, and having the iron girder rail securely fastened to it, you practically do away with any vibration. This is perhaps more expensive than the other methods, but economy is not always in the first cost of an article.

THE USE OF THE STADIA IN TOPOGRAPHICAL WORK.

BY ARTHUR BEEBE.

The use that modern engineers make of topographical maps is very limited, much more, in fact, than it should be; and this, I think, because of their high cost when made by the older methods, and the supposed inaccuracy of the method by telemetric measurement. It is surprising that prejudice and conservatism should so long prevent the use of the stadia for all topographical work, and that the use of topographical maps should not be greatly extended.

The most important engineering work at the present time is railroad location, and we will consider first its advantages for this work. The topography required for railroad location is for the purpose of securing easiest practicable grades, and reducing cost of earthwork to a minimum. Commercial considerations usually require that the line should connect certain points not far distant from each other, and a careful reconnoissance will decide about what the route will be. The actual location of the line along this route will depend to a large extent upon who is engineer, each having ideas of his own about it, which shows, I think, that there is generally considerable guesswork about it. The old English method was to make a complete trigonometrical as well as topographical survey of the route, including the surrounding country, and by the slowest and most expensive methods, but when we commenced railroad construction on a large scale in this country, we found this too slow and expensive for us. We therefore substituted running preliminary lines and located by cut and try methods, backing up and trying again until a satisfactory location was obtained, and very many lines were constructed with no more study than this. But with a demand for better work, more attention is being given to topographical maps, as aids to location.

The topography required for railroad location is a strip, say, one-half mile wide, covering the general route selected by the reconnoissance, and in ordinarily open country, unless nearly level, I would dispense with preliminary lines entirely, and substitute a complete topographical survey, made with alta-azimuth and stadia. The object of the preliminary survey is to obtain information, and it generally costs no more to obtain a correct map of a strip one-half mile wide, showing by contours correctly its hills, hollows and complete shape of ground, together with all important natural and artificial objects, than to obtain a single profile with transit and chain, which does not give as complete information as is desirable, for it does not tell us what the effect of a deviation would be, and we are inclined to accept the preliminary as a finalty, and to confine our efforts for improvement to adjusting the grade line to the surface, especially if, as is generally the case, the "General Manager" is finding fault with the expense of the survey.

The person that makes the final location should make the topographical survey, for he can thereby best study the ground he has to work on, and I do not believe in a paper location. There are other considerations than merely amount of cuts and fills; this will depend much on the character of the ground, and must be seen and noted. He should be provided with instrument having vertical circle reading to ten seconds at least, and a first class telescope of fifty diameters. He should have with him a recorder and an abundance of rodmen. Then following a main line as near center of strip as may be, he should select commanding points for stations, and cover the ground with sufficient number of observations to completely represent the ground and all important natural and artificial objects. Having finished observing at a station, and the recorder having computed heights of all observations, take your instrument box for a chair, and plat your work then and there, using engraved protractor sheets with parallel ruler or triangle and straight edge for transferring readings, and of course all readings from horizontal circle will be bearings, and not angles. Having finished platting, and lightly penciled heights of points observed, take your drawing board and visit all parts of the ground

covered by the observations, drawing in the contours with the ground actually before you, and you will probably find that many of your ideas of shape of fields, buildings, etc., obtained while standing at the instrument, were wrong. A portion, at least, of your rodmen should be well trained to the work, for you must depend upon them to select points for stations, and in the secondary work the greenhorn will consider nothing of importance except fence corners and buildings, which are of small relative importance. Your rate of progress will of course depend much on the character of the ground, level ground requiring no topography, and mountainous districts very minute measurements, but in ordinary rolling country from one to two miles advance can be accomplished in a day, so that the location can be projected directly on the field sheets with confidence. The measurements will be fully as accurate as chaining, and the heights will be practically as good as direct leveling, and there will be no more need of checking by independent measurements than with chaining, nor as much so if distances and vertical angles are read in both directions between stations.

But railroad location is not the only work for which the stadia is valuable. For locating contours for drainage purposes in a flat country it is the only practicable method, and surveys of large impounding reservoirs for town supply or irrigation purposes it brings cost of work down so that, with plane table, contours can be located at each foot of vertical height, and the gauge graduated to show the amount of gallons or cubic feet remaining in the reservoir at any time.

The present practice of the U. S. Lake Survey at St. Mary's river is to locate stations with theodolite and stadia, afterwards occupying the stations with plane table to fill in details, the tables being provided with telescopic alidades and stadia. As they have unlimited resources and boats of good carrying capacity for conveying instruments, the method works very well, but is not applicable to general use. The plane table is too cumbersome an instrument to use where much transportation is required. It is used on the Geological Survey with the old method of locating by intersections for large areas, and the compass and wagon wheel tally method of

traversing roads and taking details of topography. It has nothing to recommend it.

What is the best method of telemetric measurement? This is a much disputed question. My own experience is that the worst method is the movable wire, which is to be adjusted to read one foot on the rod for each one hundred feet of distance; it is a delusion and a snare. The wires should be fixed in the ring with the cross wires, and the rod should be graduated to correspond with the wires. Better still is the prismatic arrangement invented by Robert H. Richards, which projects the image of the lower point observed upon the target used as a starting point, in much the same manner as the sextant. With an instrument for measuring small horizontal angles to single seconds, the method with two fixed targets on a horizontal bar, introduced by Keuffel & Esser, gives very accurate results, and no correction of distance for vertical angle is required. It is adapted only to measurement between stations and other principal points in taking topography, and as it is not desirable to have two systems in use at one time, it is not adapted to general use.

To my younger fellows, I would say that if you will become familiar with the stadia, and use it in your topographical work, you will find you have a valuable addition to your instruments, and often a very present help in time of trouble.

THE USE OF THE PLANE TABLE.

WM. G. FARGO, JACKSON, MICH.

Believing that much misapprehension exists in this country regarding the plane table and its uses, the writer desires, briefly, to point out how this instrument may be of service to any engineer or surveyor having a mixed practice.

"For making a map the plane table is a universal instrument. It is applicable to all kinds of country, to all methods of work, and to all scales. For making a map it is the most simple, direct and economic instrument; its use renders possible the making of the map directly from the country as copy, and renders unnecessary the making of elaborate notes, sketches, photographs, etc., which is not only more expensive, but produces inferior results."

The general methods of using the plane table will not be considered here, as they are fully described in the text books on surveying. Much useful information with regard to the plane table and topographic work in general will be found in Monograph XXII of the U. S. Geological Survey, entitled: "A Manual of Topographical Methods," by Henry Gannett, Chief Topographer. This is a large quarto volume of 300 pages, about half of which is tables for the reduction of stadia readings, map projections, etc., etc. If the edition is not exhausted, a copy may be had for $1 by addressing the director of the U. S. Geological Survey at Washington, D. C.

Having occasion, within the past year, to make several topographic maps, covering considerable areas, the writer constructed a simple plane table, very similar to the traverse table used on the U. S. Geological Survey. This consists of a small pine drawing board, with a five-inch needle set into its upper surface near one edge. A spring lifter keeps the needle off its pivot except when in use; that is, the spring must be pressed down by the finger and held there in order to allow the needle

to rest on the pivot. This is an improvement over the usual screw lifter for use on the plane table, as one cannot travel about with the needle loose on the pivot, as often happens with the screw lifter. A brass bed plate is set flush with the under surface of the board, and tapped for a thumb-screw similar to those used in attaching a camera to its tripod. The wooden cap which protects the screw threads of a Gurley transit tripod was bored in the center to fit the thumb-screw, and the table mounted on the transit tripod. A wooden alidade, with open slit sights, completes the outfit, although, of course, a brass alidade is much better. The table is leveled with a detached level by means of the tripod legs. On rough work the table can be leveled sufficiently close by eye, by sighting across the top of the table at a distant horizon. It is oriented by using the needle which has a range of ten degrees each way from the zero line, which is parallel with the edge of the board, or it may be oriented by back-sighting to the last station or some other point already platted on the sheet.

For maps on a scale not larger than eight inches to the mile, many distances can be ascertained with sufficient accuracy by pacing or by counting the revolutions of a wheel, when not conveniently found by intersections. Section and quarter-section and eighth lines serve as bases and as checks on location by intersections. It is surprising with what accuracy one may ascertain distances by pacing, after some practice, especially along smooth roads or on railroad tracks. Along many railroads the station stakes at each 500 or 1,000 feet serve a useful purpose when using the traverse table, and a considerable belt of country each side of the railroad or highway can thus be covered without leaving the road. In an unsettled or timbered country it will be necessary to run some traverse lines with transit and stadia to serve as base lines and "control" for the plane table. If elevations are desired, a small telescopic alidade is necessary. The Casella type, used by the U. S. Geological Survey, seems well adapted, except for very large scale maps.

Maps showing marsh and lake outlines, streams, etc., for use in drainage assessments, can be rapidly and accurately

made with the traverse table described, and when the field work is completed the map is ready, except inking in or tracing. No tedious plotting of stadia readings in the office, where it is sometimes found, when miles away from the ground, that there is evidently an error somewhere. With the plane table there are so many chances to check in known points at all stages of the work that any error of importance would be discovered and rectified before leaving the locality.

Maps for use in court and working topographic plans for the location of the curved drives and paths of cemeteries, parks and suburban residence grounds, are cheaply and accurately made with the plane table.

With the simple traverse table described above the writer has had no difficulty in mapping a square mile of average Southern Michigan farm and timber land per day, on a scale of eight inches to the mile, and showing accurately all natural features and culture, fences, ditches, etc. Elevations are not shown except the more prominent hills and slopes by hachures.

There are, of course some drawbacks to the use of the plane table. If a large board is used, it is an awkward instrument to carry through brush or timber. It is not a convenient instrument to use in rainy or very cold weather, or in high winds, but as transit and stadia work is also dependent for best results on good weather, these objections are not so serious as they might appear.

REDEMPTION OF SHIFTING SANDS.

E. W. MUENSCHER, C. E.

A few months ago, while reading the "Transactions of the American Society of Civil Engineers," for December, 1894, the writer noticed in a paper by B. W. DeCourcy, C. E., on the "Improvement of Gray's Harbor," the following statement: "The neutral line mentioned, where the sand meets the silt of the river, indicates a deposit of sand brought in by the flood tide, but there is also another cause for this deposit, viz., the prevailing storm winds from the northwest and southwest. This traveling of the sand can be both seen and felt, but can be easily remedied by the cultivation of the *Arundo Arenaria*." This paragraph re-awakened a long slumbering interest in a subject which is of much importance to many citizens of this State.

Along the western and southern shores of Lake Michigan there are many long stretches of sand hills or *dunes*, some of which rise to a height of 100 feet or more, and extend for miles along the shore. These dunes are composed of very fine sand which has been washed up by the waves and then blown up and driven forward by the lake winds until its progress has been arrested by a tree, bush, large stone or other obstacle, around which it has accumulated in great masses. Some of them are covered and held in place by a thin growth of coarse grass, while others are entirely naked, and when the surface is once broken the sand drifts like snow before the winds, and the dunes often become crawling monsters, burying roads and houses, fields and forests, under their resistless and desolating tread. For agricultural purposes they have been utterly worthless, and, even when harmless, their barren, yellow slopes present a very bleak and desolate appearance, and make the scenery of some of our lake cities anything but attractive. The writer has often gazed regretfully on the forbidding-

looking ridges which surround and disfigure the city of his adopted home, and felt that if some practicable means could be discovered by which they could be clothed in living green, the relief to the wearied eye would alone sufficiently warrant the cost. But if, in addition to this, we could find a remedy for their destructive progress and a means of fitting these now waste ridges for the uses of agriculture, we should be well rewarded for the effort which had brought about such results. And if, still further, we could add the possibility that the same measures which would redeem these dunes might be used to cover with pastures and orchards and forests the worthless and uninhabitable sand plains and old choppings which cover so large a part of Northern Michigan, the effort becomes so much the more worthy to be made, for it might add millions to the wealth of the State. For years this has been only a dream, but, encouraged by the paragraph which has been quoted with a hope that it might possibly become a reality, the writer has been gathering such information as he has been able to obtain as to what has been accomplished elsewhere, and now lays it before this Society in the hope that some of its members may be able to make valuable use of it, and, perhaps, add to it from their own stores.

We are not alone in our possession of these undesirable features, though, until very recently, we seem to have been alone in our neglect of them. France, Holland, Prussia and Denmark, as well as some portions of England, Ireland and the Scottish Isles, have been cursed with great tracts of just such soil, which bear the various local names of Landes, Polders, Klittens, or Downs. Johnson's Cyclopedia, article "Dune," says: "They often do great damage by their inroads upon the country, the department of Landes, in France, having been nearly overwhelmed by them. The annual progress of the sand is estimated at 72 feet." These French dunes "extend along the Gulf of Gascony, from the mouth of the Adour to that of the Garonne, a distance of 150 miles, and have an average breadth of 3½ miles, covering an area of about 300,000 acres. Their extreme height is 330 to 350 feet. The advance of these sands had been going on for ages, cover-

ing up whole districts of farming lands and entire villages." Nearly the entire length of the sea-board of the Netherlands is a sand formation, which attains a width in some places of 5 miles. The area of this formation is estimated at 140,000 acres. Nearly the entire sea-board of Schleswig Holstein and the western coast of Denmark, to the extent of about 190,000 acres, is covered with what was, a few years ago, drifting sand. A great part of the Baltic coast of Prussia is covered by dune sands, which are known as the Pomeranian Downs, and embrace an area of more than 50,000 acres.

It was not till the year 1787 that the first attempt was made to reclaim these downs upon rational principles, and it is to M. Bremontier, then chief engineer of the department of the Gironde, that the credit is due. Since that time great progress has been made, and now not less than 230,000 acres of the French dunes, 100,000 acres of those of Holland, two-thirds of those of Denmark, and a large part of those of Prussia have been reclaimed, and the greater part is under cultivation.

The success of the system by which this reclamation has been effected depends upon the fact that "although the whole mass of sand composing the dunes may be entirely removed under the action of the wind, the transportation is effected grain by grain; that is, the top grains are first rolled away by the wind, and those next underneath coming to the surface are carried away in their turn, and so on. Therefore, if the grains on the surface are held in position, there is nothing to fear from those that are underneath, and the whole down is rendered immovable. A temporary immobility may be obtained by covering the soil with branches and boughs," but for permanent results resort must be made to living plants, and experience has shown that Nature is abundantly able to do this work if properly directed and aided by art.

It would seem, at first sight, that, as these dunes are composed apparently of pure sand, no plant life could exist for want of moisture and organic food, but experience shows that they all contain at least a small proportion of matter which plants can appropriate, and that the fineness of the sand

enables it to hold a considerable amount of moisture near the surface by capillary attraction. M. Goury discovered that upon the highest inland dunes, where the texture of the sand was the finest, perpetual moisture was present at a depth of 4 inches below the surface, while near the shore, where the sand was coarser, the line of moisture was a foot below the surface. The water from the dunes on the North Sea coast is brought by aqueducts into the interior, and the best water used at Amsterdam is said to come from this source.

With these facts as a foundation, the system of reclamation has consisted of two distinct operations: 1st, arresting the sands brought upon the beach by the waves; 2d, holding the already drifted sand of the dunes themselves by the production of vegetable growth thereon. The first is now usually effected by the building up of a new dune between the old ones and the beach, which protect the old dunes from the action of the winds while the process of reclamation is going on. This is accomplished by the use of what are called "palisades" or "fascines." The "palisade" is substantially a fence "made of boards about eight inches wide, and separated from each other by intervals of about one and one-eighth inches. When the sand is carried along by the wind it strikes against this obstacle and accumulates at its base; then, under the effect of its own weight, it passes slowly through the intervals left for this purpose, or, so to speak, it strains through the fence and deposits simultaneously on both sides. Thus a mound is formed and the boards gradually covered up by the sand." The boards are then raised and the process continues. "In place of board palisades, or jointly with them, 'fascines' are frequently employed, composed of stakes from five to eight feet in length, from two to three inches in diameter at the middle, driven into the sand twenty inches, and placed at intervals of twenty inches. These stakes are afterward woven together about twenty inches above the ground, either with brush from five to six and one-half feet long, placed end to end, or with marsh grass rolled in rope shape and about four inches in diameter. When this first woven work is nearly covered up with the sand which it stops, a second fascine

woven work, twenty inches high, is put on, and this work is repeated in the same way as fast as the sand is brought in until the woven work reaches the top of the stakes. Then the stakes are raised with clawed handspikes, and the same work is then recommenced. These artificial dunes finally reach a height which makes them an effectual protection to the dunes in their rear from any further encroachment from without. It is probable that along a large portion of the Lake Michigan shore the construction of this protecting dune will not be necessary, for the reason that the present hills have reached a height which would be a sufficient protection to the country behind them if they themselves could be protected from erosion.

The second operation in the process of reclamation, or the reclamation proper, consists in clothing the drifting sands with vegetation which will hold them in place. It has been demonstrated by European experience, that "the plants best adapted to cultivation on sand dunes, may be divided into two classes. The first embraces those trees and shrubs which have very long tap roots, diving down into the body of the formation for the sustenance which shorter rooted plants would not be able to find in sufficient quantities. The second includes such grasses and creeping plants as throw out numbers of interlacing fibrous roots, persist in pushing their tops above the drift which may cover them, root afresh at every joint so covered, and thus build up a hillock, throughout whose bulk their ramifying rootlets extend for themselves. The plants of the former class will not admit of much sand being drifted over them, and should therefore be used only where the movement of the surface sand has been stopped. Those of the latter class will not flourish to their fullest extent unless there is a constant fresh supply of the silicious particles blown upon them." They are therefore best adapted for the work of binding together these drifting particles, and when this work has been accomplished and the movement has ceased, they perish, and their decaying remains furnish organic matter for the nourishment of other and more nutritive and valuable plants.

There are several species of plants of this class which have

been used with more or less success, but the one which stands at the head of the sand-binders, having proved itself far superior to all others for the coast plantations on all the great works of reclamation, is the *Arundo arenaria* or *Psamnia arenaria.* This plant is known by a great variety of names as "mat-grass," "mat-reed," "mat-weed," "sand-reed," "beach-grass," "sea-grass," "marum" or "marrum," under which it has been used at many points on the coast of England, to reclaim sandy tracts. It is planted on the shore dunes of the Prussian sands, where it is known as "hugelrohr." It is the principal agent in the work of reclamation on the Danish dunes, where it is called "klittag" (sand sedge). Nearly all the dykes of Holland are covered with it and much of the drifting sand waste of that country has been reclaimed by it. It is there called "helm" or "dach grass." The French call it "Roseau de Sables" and now accord it the precedence for the beach plantations.

"It is a strong and rapid growing reedy grass, which throws out its roots horizontally and rears its leading stalks diagonally upward. It sprouts new roots and new leaf stalks from each bud covered by the drift, and thus spreading through the sand, finally binds it by a perfect network of vegetation. So far from being injured, it is seemingly refreshed by a shower of drift sand, and dies out when complete reclamation has been attained, and other plants take its place."

Mr. W. H. Hall, C. E., in a report to the Board of Commissioners of Golden Gate Park, San Francisco, to which the writer is indebted for much of the matter of this paper, says: "It should be raised from seed in the moist valleys and near the beach of the San Francisco downs, whence the roots, plants and cuttings may be transplanted to the beach for the purpose of erecting and maintaining the shore dune, and to any other portion of the drift, when desirable. Its growth from seed on the dry dunes is too slow during the first year to allow of its being raised in this way where it will be exposed to much drift."

Next in order of efficiency for sand reclamation purposes to the above plant, is the *Elymus arenarius* or *sea-lyme grass.* This is "a strong, rough, glaucose grass, which has been employed successfully in the maintenance of shore dunes in

France, under the name of "Courbet." It has been used to a great extent on the Holland downs and sea dikes, and although it is not as effectual a sand reclaimer as the "mat-grass," it is sometimes preferred to it for the reason that its straw is useful far many domestic purposes. It has been used in reclamation on the Baltic dunes of Prussia, where it is called the "sand-hair grass," and is preferred to the "mat-grass" for inland plantations. It has also been used very successfully in England. This plant thrives best when receiving fresh supplies of drift sand over it occasionally, but throwing out its shoots more nearly horizontally than the "mat grass;" does not grow through the sand and cover it as quickly and effectually as the latter. It may be raised from the seed on the higher portions of the dunes, but it is safer to propagate and use it in the manner prescribed for the "mat-grass." "

These two plants seem to flourish in the most arid and exposed situations without protection, and are therefore the best adapted to bind the particles of sand together, and prevent their drifting, which must be the first step in the process of reclamation. It may therefore be of interest to enquire how this work is done.

The writer is indebted to B. W. DeCourcy, C. E., for the following facts: "Rev. W. L. Rham, in 'Flemish Husbandry,' describes the improvement of poor, white sand. Trenching and leveling is the first operation, then the sowing of broom. In three years, he states, the land can be used to raise buckwheat, and from that on, by aid of manure, it becomes quite fair for raising rye, potatoes and some other crops. Mr. McLeod, of the Island of Harris, adopting another method, has brought into permanent useful pasture, a number of acres of useless drifting sand. He cut the plants of the *Arundo arenaria*, or bent grass, about two inches below the surface of the ground with a sharp spade. These are carried to the drifting sand and planted in holes eight or ten inches deep, and a handful is put in each of these holes, which are about one foot apart. Neither wind, rain or frost destroys this grass; it is excellent for wintering cattle on, and in three years, white or red clover will grow amongst it, provided it is well secured."

Mr. J. S. Polhemus, U. S. Asst. Engineer, in a letter to the writer, says: "In connection with the improvement of the entrance to Coos Bay, Oregon, and in fact as part of the project, we set several small plantations of the *Arundo arenaria*, or "Holland grass," chiefly as an experiment to see what plants were best adapted to grow on the black sand spit, and arrest the movement of the drifting sand under the action of the strong ocean breezes. We obtained the bunches of roots from the Golden Gate Park, San Francisco, Cal., where the grass has been very successfully used to reclaim a sandy waste and transform it into a beautiful spot by subsequent plantings of trees, shrubs, etc. We planted about six acres, by dividing the roots up into bunches about as thick as your wrist, and setting them four feet apart each way, and about fourteen inches deep in the sand. They were planted in early spring (April 1st), about three or four years ago, and the grass, although in a very exposed place, has grown and flourished and spread. It is the only thing we have been able to make grow, although we have tried many other plants. We never tried to sow the seed. I believe it is used in Holland and Denmark to reclaim the sand dunes along the North Sea. I think the grass would thrive in the climate of the Great Lakes, and be the best thing you could first plant."

The holding of the drifting sand, which is the object of the use of these plants, may also be accomplished by covering the surface with rows of boughs or brush. In France, these rows are laid "with the big ends of the branches toward the sea, and the twigs of the following row covering the big ends of the row previously laid on the ground, The arrangement of the boughs is therefore similar to that of roof tiles. The workmen lift big shovelfuls of sand taken from the portion upon which the cover is not yet laid, and put them upon the spread twigs. These shovelfuls are about two feet apart, measured from their centers, and suffice to hold the covers in place. The gang thus works backward." The drifting of the sand may also be arrested by the use of the palisades or fascines, as already described, but the effect of either of these methods is only temporary.

In the Golden Gate Park, the temporary stoppage of the drifting of the sand was sometimes successfully effected by sowing common barley broadcast. It sprouted from the seed on the fifth day after sowing, and attained a height sufficient to hold the drift on the twelfth day, and thus protect the slower growing plants whose seeds were sown at the same time. Mr. Hall thinks that possibly, buckwheat and chicory would answer this temporary purpose equally well.

After the drifting of the sand has been checked by either of these means, the process of clothing the dunes with permanent vegetation can commence. In the Golden Gate Park, this permanent vegetation is first prepared for by sowing with the barley, the seeds of two species of the Lupine family (*Lupinus arboreus* and *Lupinus albifrous*). "The yellow lupine of that climate is a hardy, perennial, half-shrubby plant, attaining a height of four or five feet, and covering an area equivalent to that of a circle six to eight feet in diameter. It lives to be three or four years old, bearing seeds abundantly after the first year. The blue lupine is a much smaller plant, seldom attaining more than half the dimensions above mentioned. It dies at the end of its second or third year, having produced but few seeds." These being short lived plants, answer only a temporary purpose and must be replaced by other plants. These are usually various species of pine. Mr. R. P. Hammond, Jr., Chairman of the Commissioners of the Golden Gate Park, thus describes the whole process of the reclamation of the sand dunes in that park. "All strong growing grasses with creeping or pointed roots are good for holding the sand. The best variety is the one planted here, viz., the Holland grass, *Arundo arenaria*. The best way to plant it is to plow the roots in, say in every third furrow drop in the roots, about two feet apart, covering them with the plow. Then plow another three furrows and drop in another row of roots, and so on. When the sand drifts are too steep for the plow, or where there are other plants growing in patches, the way they do is to dig pits, say about twelve inches deep and the width of a spade. In the bottom of the pit, drop a few of the roots, refill the hole and press the sand down firmly with

the feet. Dig the pits about three feet apart. After the grass is planted, sow the ground thickly with lupine seeds, covering the seeds with a hand rake. The following year plant the whole about four feet apart with some hardy variety of pine."

Mr. Robert J. Kerk, U. S. Consul at Copenhagen, thus describes the methods employed on the west coast of Jutland: "The plan generally followed in Denmark is to plant a belt of young trees (*Pinus montana or Pinus alba*), and then sow the sands, both in front and behind this belt, with the grass seeds known as *Arundo arenaria* or *Elymus arenarius*, using about 60 pounds per acre. Young trees can be had at a cost of about $2 per thousand. The seed is generally ready for shipping in the month of October, and costs about twenty cents per pound, bags not included. The trees should be planted and the seed sown in the fall or early spring. The *Elymus arenarius* seems to be more in demand for this purpose, as I am informed at the depot for seeds in Copenhagen. Another first-rate grass for shifting sands is the *Lattyrus maritimus*, which, besides fastening the soil, affords a nourishing and succulent food for cattle. This plant will also grow on poor and sandy soil situated far from the sea. It costs 40 cents per pound. Orders for these seeds should be placed not later than August, as they are not kept on hand in large quantities, and time must be given to procure them. They can be had from Markfrokontoret Nysola bodgade, No. 7, Copenhagen."

Mr. Vandeheyde, Consul-General of Belgium, says, in relation to the same work: "The only material employed are the *Pinus montana*, which is used in great quantities, and the *Pinus alba*. One makes use of the *Pinus Montana* in the dryest places, i. e. on the west and south sides of the hills, and in the parts covered with heath; the *Pinus Alba* is planted where the soil is sufficiently damp without being marshy. With these exceptions, there are not used on the dunes of Jutland any of the numerous species tried by us. The *Pinus austriaca*, which they have tried to acclimate, could not survive, and experience has, it seems, sufficiently demonstrated that no other material is known which will last long enough

here, because the young plant must not only be able to live in this arid soil, but it must also be able to grow there in a normal manner. The necessity of raising these young plants in the soil which is finally destined for them is one of the first conditions of success in the cultivation of woods, and it was thus that they proceeded from the very start."

L'Echo Ostende for October 15, 1893, says of the work in Belgium: "In the damp places, advantageously situated, there have been set out leaf-bearing plants (white areleas, black and white poplars, Canada poplars, etc.), and in general plants capable of spreading in a light soil. On the parts raised, but situated back of the sand hills, there have been set out *Pinus sylvestris*, *austriaca*, *Corsica*, etc. They have in the same manner made trials of several species of Sapins. Up to the present time these plants have been furnished in great part by the nurserymen in the environs of Bruges, or from the Province d'Anvers. Experience, however, has demonstrated that they must have the nurseries in the sand-dunes themselves. These nurseries have the advantages of furnishing acclimated plants and of being cheap, and they remove the causes of deterioration to which the plants are exposed by reason of the long transportation which they must undergo from the nurseries in the interior of the country to the sand-dunes themselves."

Mr. Hall says: "Top-rooted plants, to be successfully employed in sand reclamation, must be propagated upon the downs themselves, from seed; their success depending upon the progress of the leading root, which penetrates far into the sand before the top much more than shows itself. For this reason, also, all plants which succeed upon loose sands develop very slowly at first, while they are becoming well rooted, which fact had been the cause of the failure of early attempts at reclamation in Europe, the young plants being overwhelmed by the drift before they were large enough to hold the sands; and to prevent this was the object of the protective measures, which were afterward adopted."

Mr. Hall gives the following list of trees and shrubs which have been used with more or less success:

Maratime Pine (*Pinus maritimus*), sometimes called the

French Pine or Seaside Pine. This is the tree so extensively and successfully used in reclaiming sand downs in France. It is grown from seed on the sands. The young plants develop very slowly for the first two years; they then grow faster each succeeding season, and attain, upon the French coast downs, a height of twelve feet when six years old, twenty-five feet when ten years old, and a maximum elevation of ninety feet.

The seedling plants must be protected from drifting sands and the heat of the sun, and the sand above them kept moist by being shaded by brushwood or growth of some vegetation. This pine is adapted to cultivation upon the greater part of the San Francisco downs, including the highest and most arid portions. The seed should be sown in wide rows or belts through the lupine plantation when these latter plants are one year old, and the portion thus sown in pine should be covered by the lupine bushes which shall have been removed from them.

Cluster Pine (*Pinus Pinaster.*)—This tree is a native of the sandy shores of the Mediterranean, where it is a natural reclaimer of drifting downs. It is frequently confounded with the Maritime Pine, and good authorities differ upon the subject. It is cultivated upon the downs of France and other portions of Southern Europe, where its treatment, rate of development, and growth are very much the same as those of the Maritime Pine, but it does not attain so great a height.

Mr. DeCourcy says that "the plantations of these trees, called 'pegnadas,' constitute the principal riches of the inhabitants, who are almost entirely supported by the preparation of tar and resin from the pinaster trees raised in what were formerly useless drifting sand dunes."

Scotch Fir (*Pinus Sylvestris.*)—This is cultivated successfully upon the Prussian and other northern sand-dunes from seed, and also by setting out young trees. Better adapted to a cold climate than either *Pinus Maritimus* or *Pinaster*. Although a native of northern latitudes and grown principally in moist climates, it has been successfully introduced upon the driest sandy wastes of Australia, and is highly recommended for planting in sand downs in this country.

Larch (*Pinus Larix.*)—Recently used most successfully upon European downs, particularly in reclaiming those of France and Prussia.

Tamarisk (*Tamarix.*)—A family of beautiful small trees and shrubs, of which the French species, (*T. Gallica*), and the German, (*T. Germanica*), have been extensively used in sand down plantations and on sea-side exposures in the southern part of Europe and England. These plants stand the sea winds and salt-water air better than any other shrub or tree. They are readily propagated from cuttings upon the moist places in the downs themselves. The Arabian Tamarisk, (*T. Orientalis*), is found growing in the sands of the desert where no other vegetation exists, and the African variety, which is but a shrub six or seven feet high, is a native of the sandy shores of the Mediterranean.

Japan Varnish Tree (*Ailantus Glandulose.*)—A tree of most rapid growth in sand. It has but recently come into notice for purposes of reclamation in Europe, and proven itself one of the best for the purpose.

Sea-Side Willow (*Salix Argentea.*)—Much used in the construction of shore dunes in France.

Sand Willow (*Salix Arenarea.*)—One of the best trees for sand reclamation where much moisture exists. It does not suffer much from being nearly covered with drifting sand, but throws out new roots from every joint covered, and seemingly thrives the better from being in the drift. This tree has been used to a great extent upon sand downs throughout Europe.

Sand Stay (*Lapidospermum Lævigatum.*)—This shrub or small tree is the most effectual of all for arresting the progress of drifting sands in Australia. It may be raised from seeds upon the sand down itself like the pine.

Sword Ledge (*Lepidospermum Gladiatum*) and *Coast Sheoak*, (*Casnarinag Nadrivalvis*), are recommended as two of the most important plants for binding sea sand in Australia.

Common Broom (*Spartium Scoparium.*)—A late, handsome bush, bearing a profusion of yellow flowers, which grows readily from seed on sand downs. It was one of the first plants used in France in the work of reclamation, for which purpose it

occupies a position in the front rank of the shrubs which have been tried. The broom should take the place of the lupine when the latter begins to die, at the end of the third year. It attains the height of five feet on the French downs in four years.

Spanish Broom (*Spartium Monosperum.*)—A beautiful large shrub, with sweet-scented, snow-white flowers, used successfully in Southern Europe to reclaim drift sands.

Common Furz (*Ulex Europæsus*), called by the French "prickly bromm," is a low-growing, coarse shrub, one of the first and most successful sand reclaimers used in France, but otherwise not desirable.

Some of the above mentioned plants may possibly require sea air for their successful cultivation, and would therefore not be available in Michigan, but the writer sees no reason why our own White and Norway Pines and some of the species of oaks and poplars which are found upon our sandy soils could not well be substituted for many of them, and possibly in time some valuable fruit trees.

There are also some grasses mentioned by Mr. Hall as more or less valuable for secondary reclamation purposes. Among these may be named:

Bent (*Grass Agrostis*), of which two varieties, the "common" (*A. Vulgaris*) and the "*Fiorene*" (*A. Stolonfiera*), are adapted to cultivation on very loose, sandy soils. They each possess the characteristic of spreading over a great extent of surface by means of their long runners, which root afresh at the joints, and interweaving with each other, form a carpet over the ground, which makes them useful on light soils. They do not stand being covered by drift, and hence are not adapted to the primary purposes of reclamation. They have been used successfully upon such works in England and Ireland, where showers of rain fall at short intervals, but have not received any attention as retainers on the continent of Europe.

Couch Grass (*Triticum.*)—There are two varieties of this grass adapted to sandy soils, the "common grass" (*Triticum repens*) and the "Sand Couch grass" (*Triticum janceum*), of which the latter has been used to some extent on works of

reclamation in Europe. Their habit is much like that of the "bent grass," and their long, white stalks are known to extend under the surface of loose soils for many feet.

Several members of the Lupine family, *Lupinus albus* particularly, have been extensively grown in Germany and France, where their tops when young are used for cattle fodder, and their seed fed to poultry. They have also been cultivated on poor, sandy soils to be turned under as green manure, but never before used for the purpose of reclaiming drifting sea sands.

It is highly probable that among our native Michigan grasses some varieties might be selected which would prove valuable for this purpose.

Mr. Hall states that the cost of sowing and maintaining the young forest of the French downs, exclusive of the works of protection at the beach, was about $13.50 per acre during the first years of reclamation. Of late years, owing to the advance in price of good seed and labor, the cost has been about $20 per acre. The cost of planting the grass upon the beach was about $11 per acre, and is now estimated at $14 per acre. The cost of reclamation by the use of grasses in Denmark has ranged from $10 to $15 per acre; and in Holland the expenses has been somewhat less for the plantations.

It is estimated that the cost of reclamation of the San Francisco downs with lupine will be less than $20 per acre, that the subsequent sowing and protection of the seeds will cost $25 per acre, and that the cultivation of the principal grasses will cost from seed $15 per acre, or by transplanting $35 per acre.

It will be observed that this estimate of cost applies to the case of lands which are entirely covered by drifting sands and are exposed to the full fury of the ocean storms and to constant accessions of great quantities of fresh sand thrown up by the waves, and that it is supposed to be sufficient to fit them for the purposes of an ornamental and attractive park. It is, of course, much greater than would be required for the ordinary reclamation of our Michigan dunes, where the surface is usually only partially broken, and all that is needed is the arresting of

the drift and the re-clothing of the surface with sufficient vegetation to hold it down.

The cost of erecting and maintaining the protective shore dunes by palisades and covering them with suitable grasses has ranged in France, Denmark and Prussia from 30 to 75 cents per lineal foot. In Michigan the cost would probably be greater than this wherever these protective dunes are necessary, but in a great majority of cases this would not be the case.

For any further information consult Appendix II of the Report of the Chief of Engineers, U. S. A., for 1890, and U. S. Consular Reports for September, 1895.

DISTINCTIVE FEATURES AND ADVANTAGES OF AMERICAN BRIDGE PRACTICE.

BY EDWARD BARRINGTON.

It is not the purpose of this paper to enter into the minutiæ of a subject so vast, upon which volumes have already been written and volumes more might still be written, but simply to pass in review the characteristic features of that practice, which, dating from 1833, when August Canfield took out the first patent for an iron truss bridge, and continuing down to the present day has given to American bridge building operations a new significance.

American bridge practice in its generic sense and world-wide significance dates from 1851, and really all that is valuable, all that is remarkable or worthy of discussion, is embraced in the experience and achievements of the past forty-four years. Back of that we find pretty much the dead level of mediocrity, a general, almost universal, employment of "rule of thumb" methods. The application of scientific principles and methods was extremely rare.

So much has been written upon the important subject of bridges that, perhaps, it might be considered as well nigh exhausted, were it not that there is no end to human ingenuity.

It is, therefore, with feelings of diffidence the author ventures to present a few remarks which he has somewhat hastily committed to paper, trusting that the practice in this line of our profession may interest some of the members of the Michgan Engineers' Society.

Some of the matter presented, such as the long list of comparatively obscure bridges, may prove wearisome, and a more elaborate description of famous bridges of recent construction would no doubt be more interesting, but the author

trusts that allowances will be made, when it is remembered that this is the contribution of a busy man who takes the liberty of laying before the Society information which has been hastily collected and put together, without garnishment of any kind.

It is needless to say that he does not claim originality for most of the matter contained in this paper. In its compilation he has liberally culled from more or less recent productions of such able authorities on bridge construction as George S. Morison, Theodore Cooper, A. F. Robinson, and others of prominence too numerous to mention.

The author regrets that there is not more reference made to the practical side of the subject, and that he permitted himself to dwell so largely upon the historical; however, he trusts some future opportunity will present itself, when it will be possible to enter upon the former branch of this very interesting professional study.

The practice here, now, tends to great simplicity of design, and in this, we believe, America excels all other nations.

It has frequently been remarked that of the many bridges which cross the Manchester Ship Canal, all built at once, there are no two alike. This must have had the effect of greatly increasing the engineering work and expense, and led to much unnecessary complication.

A cursory glance at the development of the art of bridge construction reveals a series of interesting facts:

First—That masonry arch bridges, from their simplicity, elegance, permanence, and strength, have in all ages been the most favored forms of construction for highways, and that the use of iron and steel has in no way changed this popular favor, except when the employment of these materials is either favorable to economy or to the introduction of larger spans. For railway bridges, other considerations favor the use of iron and steel.

Second—The introduction of cast-iron arches, though favorable to architectural elegance of design, has not resulted in any permanent useful developments.

Third—Timber bridges have in all ages been regarded as

temporary structures, which were to be replaced sooner or later by others more permanent in character.

Fourth—The springing up and immense development of the railway systems of the world within the last sixty-five years, and the concurrent progress made in the metallurgy of iron and steel, have given rise to entirely new problems in bridge-building and to a new branch of the engineering profession.

Fifth—The demands of railway traffic for direct lines which must surmount every obstacle regardless of cost, either by tunnels or bridges, the heavy weights transported, and the great speed of trains required, have directed, for a time, public interest from the highways, formerly, in the time of the old stage-coach, the only subject of consideration.

Viewed as intellectual and mechanical achievements, the bridges of modern times may now be classed with the steamships, locomotives, and pumping engines, which could not have been suggested a hundred years ago by the most vivid imaginations.

They are triumphs of science rather than art, and as such we would, perhaps, be content to look at them; deriving our interest from cold, impassioned reflection upon the thought, the genius, and the skill required to produce them, rather than from any such pleasing æsthetic emotions as arise when we look upon some of the works of the older bridge designers.

The construction of a line of land travel, of course, involves numerous bridges, rude and cheap in primitive times, but exhibiting elements of a more permanent character and more pleasing architectural features as a country advances in wealth, education, and civilization. There are few structures which more truly indicate intellectual cultivation and general prosperity than the bridges found along the lines of intercommunication more even than the roads themselves. It is unfortunate that the necessities of railway traffic have caused the introduction of forms of construction in iron here and there which mar delightful landscapes, and which contain no lines of grace perceptible to anyone except the engineer, who alone knows how much intellectual labor these uncouth skeletons and monsters have cost.

At present we may place bridges in four classes, as follows:

1. Beam or girder bridges.
2. Framed truss bridges.
3. Arch bridges.
4. Suspension bridges.

The framed truss is generally used for railway bridges, as it is economical, having the maximum of strength with the minimum amount of material. The I-bar, or flanged girder, is one of the most generally used forms of construction for bridges of short spans. Next in order comes the framed truss or framed girder bridge, the whole foundation of which is based on a triangle, which is the only figure the form of which cannot be changed without changing the length of one of the sides; and thus any truss to be perfectly braced and able to withstand any stresses that come upon it, must be framed so as to be divided into a series of triangles.

The simplest form of framed truss is the king post truss. The next is the queen post truss. Either of these trusses can be inverted so that the truss comes below the floor; the only difference that it makes is in the character of the strain that comes upon the different members of the truss. The vertical member of the upright trust is in tension, but when the truss is inverted it is in compression. The braces become ties, and the floor stringers are in compression. When it is desired to make the floor come upon the top of the truss, then the bottom chord or tie-rod can be omitted entirely, and the horizontal thrust taken by means of masonry abutments. There the weight comes directly down from the top of the bracing, and the lower end of the braces are held in place by the masonry abutments. From some combination of these trusses any form of bridge can be constructed. All bridges are composed of two or more trusses, which can be connected at the top and bottom. In the pony truss the only distinctive feature is that the trusses are not deep enough to allow of their being fastened together across the top, when the trains run upon the bottom chords, and they can only be used for short spans, and it is difficult to brace them so as to keep them in a true vertical plane. When pony trusses are used as deck bridges, they can be

braced so as to form very firm bridges; practically they are simply box girders.

The top and bottom members of each truss are called the chords, which are usually parallel to each other. In some types of truss bridges there are no bottom chords, as, for example, the Fink truss. For short spans it is a most convenient and economical method of construction and has been much used. In long spans the bottom chord is put in to add stiffness and stability. In the Bollman truss no bottom chords are necessary, the distinctive characteristic being that the tension members run directly from the lower end of each vertical compression member. In this respect they differ from the Fink truss. Theoretically this is the simplest bridge that can be constructed; but when the spans become of any great length, the tie-rods become unmanageable. In railway bridges the trusses are all some combination of the king post truss, either upright or inverted. The most common is known as the Howe truss. In this the braces are diagonal, and the tension members vertical. Although not an economical truss, it is much used owing to its simplicity of construction. A very large "factor of safety" has to be used in all Howe trusses owing to the uncertain character of the wood; this is never less than five and frequently ten. Of course the Howe truss can be used either as a deck or through bridge. Many remarkable examples of this type of bridge have been constructed in the United States, designed by ordinary carpenters, who had received not a particle of technical education, which have been very durable.

As iron decreased in price, a very economical type of bridge came into vogue, in which the lower chord was made of iron in place of wood; it was called a "combination bridge," that is of iron and wood. The next form was the Pratt truss, the distinctive feature of which is that the compression members are vertical, while the tension members are diagonal or inclined. In this type the amount of iron is increased and wood decreased, supposing the tension members to be of iron and the compression members of wood. In a short time the wooden posts were removed and iron posts substituted, and then we had an entire iron bridge, in which compression mem-

bers are vertical and tension members inclined. This is the "typical American railway bridge." The next form of truss was the Warren triangular girder, in which each of the pieces connecting upper and lower chords act both as ties and braces. The only advantage claimed for this bridge is simplicity and fewer number of parts than any other form of bridge truss. But, by reducing the number of parts, the sizes were increased, and thus much of the advantage was lost. When this type of bridge is used as a deck bridge and a floor system is laid on top of the chord, vertical posts are necessary, but for a through bridge they are not required. Where good timber of large size can be procured, this is as economical and convenient a form of truss bridge as can be built. The lower chord must be made of iron, but the tie braces and top chord of wood. A complicated method of fastening the tie braces is necessary, as they have to resist both tension and compression. A great advantage in using this kind of truss is the ease with which any piece can be removed and replaced by a new piece without suspending traffic. The Post bridge is the last type that has been used to any great extent in this country. Its characteristic feature is that the compression members are inclined at what is claimed to be the most economical angle, considering the amount of strength obtained for the amount of material used. They are so inclined as to cross one panel of the bridge, while the tie-rods, running at an angle with the braces, cross two panels. This is the only advantage, and it is more than counterbalanced by some of the difficulties encountered in the actual construction, and it is doubtful if this type is really more economical than the Pratt.

The author will not elaborate on the bowstring girder, masonry-arch, or suspension class of bridges at present, as he feels sure all are more or less familiar with their peculiarities of construction. He will merely add, that there are inherent defects in the suspension type which render it inapplicable to rapidly moving heavy loads, which will always be a sort of bar to its general use. For excessively long spans it has no equal for slow moving loads.

The last type he will dwell upon is the cantilever, in which

the variations are almost infinite, although the principles are the same in all. In the bridge that crosses the St. John River, at St. John, New Brunswick, the upright trusses are used to support a framed truss in the center; whilst in the bridge across the Hudson River, at Poughkeepsie, the trusses are inverted, the ties becoming braces, the floor comes upon the top, the shore ends being firmly anchored, and the suspended span held in place. Where great length and increased strength is desired, a combination of the two is resorted to as in the case of the Forth bridge. By using the cantilever, we gain the following advantages for long span bridges: (1.) As a substitute for the suspension bridge it is, up to a certain length of span, less expensive, and it can be given great rigidity and stability. (2.) As a substitute for the framed truss it requires no false work for its erection. And lastly, it is possible to transfer the weight of the superstructure exactly to the centre of the pier instead of placing it near the edge of the pier, as must be done with separate spans. Many claim that cantilevers are a modern invention; such is not really the case, as there now exists in Japan as perfect and scientific a cantilever bridge as any either here or in Europe, which was built by order of the Mikado 250 years ago.

In timber bridges America has taken the lead of all other countries; the only structures in Europe comparable with them are the Schaffhausen and the Wittengen bridges across the Rhine. A famous bridge of timber called the "Colossus of Fairmount," was erected over the Schuylkill, at Philadelphia, by Louis Wernwag, towards the close of the last century. It had the form of a very flat arch, 340 feet span. Its slender, graceful appearance was much admired, Fanny Kemble comparing it to a "scarf rounded by the wind, and flung across the river." It was destroyed by fire in 1838.

Timothy Palmer built several notable bridges, one of which crossed the Schuylkill, at Philadelphia. The construction was a combination of king posts and bracing with the arch. Among notable designers of timber bridges during the early part of this century appear the names of Burr, Towne, Long, and Howe, the two latter having followed Towne, and produced

modifications of his truss, to which their names have since become attached. Towne's truss was such a remarkable and important improvement—the application, in fact, of a new mechanical principle in bridge building—that it was immediately extensively copied; the most important example being the bridge erected across the James River, at Richmond, built by Moncure Robinson. The length of this bridge was 2,900 feet. It was supported by eighteen granite piers, at distances apart, varying from 130 to 150 feet, and cost $100,000, or about $3,500 per lineal foot.

Other bridges on the same principle were built, one across the Susquehanna, 2,200 feet long, with one span of 220 feet; others erected at Nashua, N. H., Newburyport, Springfield, Northampton, Philadelphia, Trenton, near New York, another near Troy, and many others in the Southern and Middle States. These bridges have nearly all disappeared, wrought iron having taken the place of timber, while the principle of Towne is still preserved in the new material of construction.

Some forty odd years ago an English writer remarked that American timber bridges "looked like coffins for sea serpents," because they were boxed in to preserve them from decay and snow-drifts, although giving their design pre-eminence. Now, the coffin is removed, and the skeleton, transmuted into iron, is fully exposed to view. The only wrought iron bridge in the United States which has elicited from travelers expressions of delight, owing to its architectural elegance of design, is the Girard avenue bridge in Philadelphia, which was built under certainly favorable circumstances.

As early as 1787 the need of a material for long span bridges more suitable than wood was considered necessary. In 1803 Thomas Paine advocated the construction of iron bridges. The only iron bridge then existing was near Coalbrook Dale over the Severn. No further consideration seems to have been given the subject until 1830, when Long and Towne—who were experts in the construction of wooden bridges, as already mentioned—both suggested that their bridges could be made in iron and wood. In 1833 August Canfield took out the first patent for an iron truss bridge, and

Mr. Earl Trumbull in 1840 built the first iron truss bridge over the Erie Canal at Frankford, N. Y. In the same year Squire Whipple, built his first iron bridge. In 1846–47 James Millholland built a boiler plate tubular girder fifty-five feet long. In 1846 Frederick Harbach patented an iron Howe truss. About 1847–50 Nathaniel Rider built a number of bridges of iron; the failure of one of these bridges in 1850, following the failure in England of a bridge over the river Dee, influenced the officials of the Erie Railway to direct all iron bridges to be removed and replaced with wooden structures.

About 1851, Mr. B. H. Latrobe, chief engineer of the Baltimore and Ohio Railway, gave the first impulse to the general adoption of iron bridges. He had previously much experience in the construction of wooden bridges in which iron was extensively used. In 1852 a Bollman truss, 124 foot span, was built at Harper's Ferry. In 1851–52 three spans of 205 feet each on the Fink plan were built over the Monongahela River. In 1852–3 Squire Whipple built a double-intersection Pratt truss iron bridge, of 146 feet clear span, near Troy, N. Y., which continued in use until 1883, although it was only proportioned for a rolling load of one ton per lineal foot. From 1851–61 the Pennsylvania Railway built many iron bridges from 65–110 feet span.

In 1857 F. C. Lowthrop built his first railway bridge. It consisted of eleven spans, total length 1,122 feet, supported on iron trestle towers.

In 1858–59, J. W. Murphy built a Whipple bridge, of 165 feet span, at Philipsburg, N. J., which was the first truss bridge pin-connected throughout. In 1861 J. H. Linville built a bridge over the Schuylkill River, in which wide forged eye-bars and posts, formed of wrought-iron sections, were used for the first time. In 1863 J. W. Murphy built a bridge at Mauch Chunk, in which he used wrought-iron for both the posts and top chord sections. This was the first American truss bridge in which the tension and compression members were of wrought iron. He used, however, cast-iron joint blocks and pedestals. In 1865 S. S. Post built the first Post truss iron bridge at Washingtonville. Between 1865 and 1880 many bridges of this style

were built. In 1859 Howard Carroll began building riveted lattice bridges, mostly of short spans of 40-90 feet. The excellence of Mr. Carroll's work, gave the preference to this class of bridge on many railway systems. In 1874 Mr. Charles Hilton built a bridge of this style across the Connecticut River, having seven spans of 180 feet each. The author neglected to mention that Mr. Felician Slataper built a bridge over the Allegheny River in 1864, having five riveted lattice spans of 178 feet each, and in 1865–66 Fairbairn & Co., of England, built an iron lattice bridge over the Connecticut River, from designs by James Laurie, the longest span being 177.25 feet.

Long span bridges date from 1863–64, when the first bridge was built over the Ohio River, at Steubenville, by J. H. Linville. The channel span was 320 feet long and twenty eight feet deep. This was followed in 1868–70 with one over the same river at Louisville, built by Fink, with two main spans of 360 and 390 feet. In 1870 Linville built a bridge over the Ohio River at Parkersburg, with channel spans of 340 feet, and in 1872 he built the Cincinnati bridge over the same river, with a channel span of 420 feet. During 1868–74 J. B. Eads built the St. Louis bridge across the Mississippi River, containing two arches of 502 feet and one clear span of 520 feet. In 1876 the Cincinnati Southern Railway bridge over the Ohio River was built from designs by Linville and specifications by Bouscaren. The channel span was 519 feet, the longest truss span built up to that date. The channel span of the Henderson bridge, and of the Ohio River bridge of the Kentucky Central Railway, at Cincinnati, are 522 feet and 550 feet respectively. There are now about seven miles of American railway bridges with spans from 300-400 feet, nearly five miles with spans from 400-500 feet, and about 3.5 miles with spans exceeding 500 feet, estimated as single track bridges, all exclusive of wire suspension bridges. The first iron cantilever bridge of importance was the Kentucky River bridge, designed and built by C. Shaler-Smith in 1876–77. It is 1,125 feet long, and consists of three equal spans of 375 feet. The second was the Minnehaha bridge over the Mississippi at St. Paul, built in 1879–80, and consisting of one centre span of 324 feet, and two shore spans

of 270 feet each. The third and fourth were the Niagara and Frazer River bridges, designed by C. C. Schneider, the first being completed in 1883, and the second in 1885. The St. John River cantilever was also built in 1885. Since that time many have been built, the one of greatest importance and magnitude being the Poughkeepsie, crossing the Hudson River near New York.

While on the subject of cantilever bridges, the author cannot well avoid referring to the Memphis Bridge across the Mississippi River, the first bridge built across that river below St. Louis. This bridge, by connecting ten lines of railroad, opens a way for traffic from the west and south-west to the Atlantic seaboard. It has the distinction of having the third longest truss span in the world. The Forth and the Sukkur (India) Bridges have longer spans. This span is 790 feet, and consists of two cantilever arms 169 feet 4.5 inches each and a central span of 451 feet 8 inches. On one side of this long span is another span of 221 feet, and on the other two spans of 621 feet each, one a continuous span, and the other a cantilever arm and simple truss. The bridge is 75 feet above high water, and 109 feet above low water.

The piers were sunk by the pneumatic process, the deepest one reaching 108 feet below water-surface. In only the east abutment of the St. Louis Bridge has the pneumatic process been used with a greater immersion, and then it was 109.7 feet. The bridge was finished April 24th, 1892, and formally tested May 12th, 1892. It ranks with the great bridges of the world.

The author would also mention, in passing, the erection of the highest bridge American engineers have yet built. The Pecos bridge has this distinction of height, and its height is exceeded by but one other in the world. It is 328 feet above the surface of the water of the stream, while the highest in the world, the Loa Viaduct, in Bolivia, is 336 feet and 6 inches high. The Kinzua Viaduct in Pennsylvania, the third highest, is 302 feet high. The Pecos River Viaduct is 2,180 feet long, consisting of 48 spans, mainly plate girders, alternately 35 and 65 feet long. The channel span is a cantilever 185 feet long. The substructure consists of masonry piers with steel trestle

towers. The highest tower is 321 feet high, 35 by 100 feet at bottom, and 35 by 60 feet at top. Mr. Geo. S. Morison was engineer of the Memphis Bridge, and Mr. Wm. F. Kendall engineer in charge of the Pecos River Viaduct.

The comparative economy of iron, combination and wooden bridges is as follows, according to the report of the Committee of the Association of Railway Superintendents of Bridges and Buildings. Assuming a span of 175 feet, and taking first cost and the saving within 20 years by using the cheaper structures, capitalized at 4 per cent., this Committee reaches this conclusion:—

Span of 175 feet.	Cost.	Saving in 20 Years over Iron.
Iron; with forged steel eye-bars	8,000 dols.	
Combination Iron with wood compression members	6,800 dols.	2,611 dols.
Howe Truss covered with Galvanized Iron	6,000 dols.	4,382 dols.

From this it appears that the net saving by building either a combination or a wooden bridge, compared with the cost of an iron structure, will not be enough to pay for rebuilding at the end of the natural life, at which time the iron bridge would still be in perfect condition. An iron bridge can be maintained 75 years, if kept painted and otherwise properly cared for, which, while a matter of opinion, seems to be justified by experience thus far gained. A wooden bridge is safe, a combination bridge is safer, and an iron bridge safest, cheapest, and best.

The author has refrained from more than alluding to the Brooklyn Suspension Bridge, as the work is of so stupendous a character as to require a whole discourse to itself. Probably the most interesting feature in connection therewith is the fact that Mr. Roebling, the famous engineer who supervised the construction of it, lost his sight from an accident in one of the caissons shortly after the commencement of the work, and completed that magnificent bridge (probably the finest in the world, taken as a whole) by dictation to his wife, a lady of great mathematical acquirements, who intelligently explained his designs to the assistant engineers as the operations progressed.

The present seems to be an era of big bridge building in both this and foreign countries. The bridge across the Mersey at Liverpool is to consist of 3 arched suspension spans of 1,150

feet, and 150 above high water, with railway tracks, roadway for vehicles, and sidewalks. It is proposed to bridge the Bosphorus at Constantinople by a structure 8,645 feet long. The Channel bridge between England and France, as at present proposed, will consist of 73 spans, alternately 1,300 and 1,625 feet in length, with a clear headway of 175 feet. Two have just been completed across the North Sea and Baltic Canal, with 150 feet spans, carrying railway tracks, roadway and footpaths. In this country the new East River Bridge at New York, as projected will have a span of 1,670 feet, a total length of 3,200 feet, a clearance of 140 feet, and will carry 4 railroad tracks. The North River bridge will have one span of 3,100 feet, and carry four railway tracks and a roadway and footpath at each side of the bridge.

The author will digress for a moment to mention the peculiar features of two bridges which run lengthwise of canyons in the Western States. The first is in the Apache canyon of the Rio Galisteo, on the main line of the New Mexico and Southern Pacific Railway. The centre line is on a 10-degree curve, and it is 14.5 inches off the centre line of the bridge at the ends and centre. The second case is in the Royal Gorge of the Arkansas River, and is known as the "Hanging Bridge." The great peculiarity is the suspension of one of the trusses from the intersections of pairs of inclined beams which rise from abutments against the rocks on opposite sides of the canyon to the point of intersection, where they abut against each other.

A curious bridge, found on the Canadian Pacific Railway, crosses a tremendous chasm, and the best way that could be seen of surmounting the difficulty was by resting the bridge on two trees which were growing in the abyss below. The tops of the trees reach the ground above, and the bridge rests upon them.

The characteristic difference which exists between American and English practice of bridge building, is in the methods used in joining together the different parts of the bridge—American bridges, as a class, being pin connected, which leaves the joints flexible; whilst English bridges have riveted connec-

tions, and each member acts simply as a part of a rigid, inflexible whole. It would occupy too much time to enter into the various causes which have led to these differences, suffice it to say that much ingenuity has been displayed by American engineers in the combination of triangles used in bridge designing, and in many cases this has led to absurdities. At present the whole tendency in American practice is to extend the use of riveted joints, and in English practice to extend that of the pin connections. Both are working in opposite directions, but from opposite sides, and therefore towards the same point. One great drawback to the use of the pin connections by English engineers, is the immense first cost of the plant necessary to do the work. Our bridges are usually designed and built by the same company, so that the designs, within certain limits, correspond to the available plant of the manufacturer, and expensive tools can be used over and over again.

In English practice, bridges are designed by individual engineers, and some firm has to build them in all their multiplicity of details to correspond with the designs. In riveted work, however, the tools required are the same within certain limits, regardless of the details of design. Pin-connected bridges are much more economical for large work than riveted ones; and this, taken in connection with the unrivalled facilities for doing the work, accounts for the fact that in the building of large bridges, American firms can underbid any others, and not in any way lower the character of the work done. A very important consideration is that pin-connected bridges can be erected in *one-twentieth* of the time required for the erection of English riveted bridges.

While the pin-connected bridge is especially the American type, our engineers have learned much from European practice. The promptness and fullness with which their works and practice have been given in current technical literature has been quickly taken advantage of by us. Another advantage has been the combination of designing, manufacturing and erecting quite intimately. Theorists and hobbyists have thus less weight here. Great uniformity exists in the styles of bridges adopted for various spans. Fifteen years ago a thousand

styles of bridge existed; while to-day there is a general approximation to certain broad types in style and detail, although no two bridges are exactly alike.

Plate girders are used for spans up to 65 feet usually, but some railway companies are using them up to 100 feet. These girders are completed at the shops. They give excellent satisfaction. Up to 65 feet they are cheaper than lattice girders; maintenance is less; security is far greater; they are cleaner; and faulty rivets make much less proportionate reduction in strength than in lattice girders.

A 182-foot plate girder swing bridge is now being built for the Washington and Chesapeake Beach Railway Company by the Youngstown Bridge Company. This will be the longest plate girder span ever erected in this country, and was designed by Mr. C. E. Fowler, Chief Engineer of the Bridge Company.

Riveted lattice girders have been quite generally used on all our railways for short spans and by some for all spans, still the preference remains for the plate girders. Lattice bridges have no merits which are not possessed by pin-connected types. They are usually limited to spans between the longest plate girders and minimum pin-connected spans; this limit is not fixed, the lower limit being determined by relative cost of plate and lattice girders, and ability of railroads to transport long plate girders, and the upper limit by the preference of the engineer. These limits are somewhere between 60 and 120 feet. One advantage of the riveted form over the pin-connected form for lower spans, is the additional stiffness of the connections and forms of members, each case determining the circumstances. Pin-connected bridges could be made equally stiff for the lower spans, and still attain perfection of fitting and lengths of parts peculiar to them, if the connections where reversal of stress occur were rigidly bolted and riveted together. Theorists might object to this, owing to secondary strains. These can be held in subjection if restrained within certain bounds. As long as friction exists, pin-connected bridges will not be free from them.

Lattice riveted bridges and double intersection trusses have not been more fully discussed, as their introduction

would only have the effect of obscuring the object of this paper.

A brief retrospect of the evolution of bridge construction suggests that, as regards form and proportion, the following mechanical principles have been found worthy to survive:—

1. The panel system, whereby the diagonal members were kept at economical angles, produced the trusses built by Palmer and Burr.

2. The principle of counterbracing these panels led to the trusses of Long and Howe.

3. The idea that diagonal compression members should be made as short as possible caused the Pratt and Whipple forms to arise.

4. The idea of varying the depth of the truss to render stresses as nearly uniform as possible brought the curved upper chord into use.

5. The methods of suspending alternate floor beams without the use of a double system of bracing, gave rise to the Baltimore truss; and lastly,

6. The combination of all these good qualities produced the form known as the bowstring or arched truss, whereby are gained, in addition, the advantages of that type, in making nearly uniform the stresses in both chords and web members. It is not intended to imply that this truss is one universally applicable with maximum economy, but merely that it appears to typify the best and most successful American practice, and renders it applicable to the longest simple spans.

The trial and rejection of many kinds is a necessary element of the progress of evolution, and in our present forms of trusses, are embodied the lessons taught by all preceding ages. At present, in a flourishing existence, as the result of this evolution, are found the Pratt, the Baltimore, and the curved bowstring trusses, the first being best adapted for short, the second for medium, and the last for long spans.

Extended investigation seems to show that under the most favorable circumstances iron bridges are not safe for a period of over 75 years; and under certain conditions their life is much shorter. The method of manufacture is of the *least* importance

in the estimate of durability. The effect of a more or less heavy traffic upon the fibre resistance in the materials of construction plays an important part, and the pounding under the train motion and the vibration due to rolling loads wear out the bridge.

With the exception of a few hundred spans, the longest of which are 260 feet lattice-bridges, the 7,645 spans of iron railway bridges of the United States over 100 feet, and aggregating 232 miles in length, are of pin-connected type. American engineers adhere to them, as their merits are strong and positive. Good bridge designs do not contain more than a single system of triangulation in their forms of trusses. Those now adopted are such as give the greatest concentration of parts, with long panels, and without theoretical or practical ambiguity of strain under a miscellaneous series of wheel loads.

Forms of members requiring cast-iron joint-boxes or other uses of this material are now obsolete. The Bollman, Fink, Lowthrop, Post, and double-intersection Whipple and Linville trusses have disappeared from practice here, and parallel chords and equal spans are generally used now; this gives a minimum number of parts, and leads to greatest economy and accuracy of manufacturing. For long spans the depth may be advantageously reduced at the end panels. The channel span of the Ohio River Bridge at Cincinnati is the longest pin-connected truss span in existence, being 545 feet from centre to centre of end pins, 84 feet deep at centre, and 60 feet deep at the end posts; panel lengths 27 feet 1.5 inches; trusses 30 feet apart, centre to centre. It carries a double-track railway between the trusses, and has on each side a wagon-way and foot-walk, 16 feet wide.

In summing up the essential characteristics of the *typical American railway bridge*, we find it is a skeleton structure, pin-connected at all principal articulations; so formed as to reduce all ambiguity of stress to a minimum; concentration of parts; facility of manufacture; perfection of lengths and fitting of all members; which reduces to a minimum all riveting and mechanical work in the field, and finally readiness with which the individual members can be assembled during erection.

The relative amount of bridges and trestles varies in different districts from 58 feet to 231 feet per mile of track. This last is excessive, as it includes the crossing of Lake Pontchartrain, near New Orleans, on a trestle 22 miles long. Omitting this, we would only have 162 feet per mile as the maximum. These variations are not entirely due to geographical location. They are affected by principles governing the original location of each road. The alignment and grade may have been sacrificed to the avoidance of bridges or trestles, or the contrary. Carefully prepared statistics show that there are 3,333 miles of bridges and trestles on our railways, or about 100 feet per mile of track on the average, which is distributed as follows:—

Trestles and Spans under 20 feet.	2,662 miles.	799,900 spans.
Spans..... from 20–50 "	132 "	19,965 "
Spans..... from 50–100 "	143 "	10,000 "
Spans..... from 100–150 "	209 "	8,800 "
Spans..... from 150–200 "	120 "	3,600 "
Spans..... over 200 "	63 "	1,265 "
Total,	3,333 "	843,530 "

The above includes all bridges of either wood or iron.

The iron bridges are as follows:—

Iron Spans under 20 feet.	19 miles.	5,610 spans.
Spans from 20–50 "	94 "	14,190 "
Spans from 50–100 "	72 "	5,600 "
Spans from 100–150 "	102 "	4,290 "
Spans from 150–200 "	76 "	2,310 "
Spans over 200 "	54 "	1,045 "
Total,	417 "	33 045 "

The records for iron bridges under 300 feet spans are very incomplete; those over 300 feet are as follows:—

Spans..... over 500 feet.	3.5 miles.
Spans from 400–500 "	5.0 "
Spans from 300–400 "	7.0 "
Total,	15 5 "

Deducting the amount of wooden trestles which will probably be filled in embankment, and the bridges which will be maintained in wood, there remain about 1,100 miles to be gradually replaced with iron bridges and trestles; spans probably may be from 50 feet to 200 feet. This would make 1,517 miles of iron bridges for the 175,000 miles of railroad now in existence, of which only 417 miles are at present built. The substitution of iron for existing wooden bridges, of course, will be gradual, so there will be no dearth of employment for our

bridge building firms for some time to come. The lineal feet of highway bridges which will be required in the same time will be about five times that required for railway use only.

Distorted reports frequently appear in foreign publications relative to railway bridge failures in the United States, which engender false impressions and conclusions. It is hardly necessary to state that these reports are collated from newspapers and not from official returns, and are full of inaccuracies. The number of failures here, due to causes or forces which a bridge should be designed to meet or resist, is an exceedingly small one, considering that there are over 843,530 spans—of which over 33,000 are iron—on our railways, and when the circumstances under which they are mostly built is properly considered, and the rapid development of our railway system, together with the enormous increase in weight of our loads carried and weight of rolling stock, which is now met by much heavier structures than formerly. The demands for cheap railways, far in advance of settlements, compelled cheap and light structures originally. Not a single all-wrought-iron American railway bridge has failed under legitimate train service. Defective and inadequate structures of the past have taught us the relative merits of the various forms and proportions of the members and their details. Our knowledge has passed far beyond the study of stresses and tests of specimens, and we do not cover our ignorance under a so-called factor of safety. We have studied the working under excessive loadings, even up to rupture, of structures and details which had outlived their intended purpose or were improperly designed from the beginning. Without some failures there would be no evolution or the survival of the fittest.

BRIDGE BUILDING, PAST AND PRESENT.

W. J. DUNCAN, ASSISTANT BRIDGE ENGINEER, M. C. R. R.

The science of bridge building, for such it has become, may be said to have had its origin and development in our country. Bridges were built in European countries in very early times, but the practice in America has been followed in a distinct line of its own. In the course of its development it has undergone such a complete evolution that to the better understanding of the position it has attained and now occupies, I will ask your indulgence while briefly tracing its course through this period of development.

From Theodore Cooper's paper on bridges the following historical information was principally obtained:

Bridge building in America had its beginning with the dawn of the new world. The pioneer was called upon to bridge small streams, and having limited resources, and no precedents, his ingenuity and skill were drawn upon and given full sway. The earliest bridges where single timbers were not sufficient to stretch from bank to bank, were short spans supported on piles, or, where piles could not be used, on timber cribs filled with stone. Where the conditions would not admit of structures of this kind, arch spans were usually adopted.

Among the early structures of note, was the so-called "Great Bridge," a pile structure built across the Charles River, between Old Cambridge and Brighton, in 1660. In 1786 a bridge 1,503 feet long was built over the Charles River at Boston, which was supported on seventy-five piers.

In 1810 a chain suspension bridge was built at Newburyport, Mass., of 244 feet span, center to center of towers, the chains being composed of links about two feet long, made of one inch square iron. The roadway was supported by two sets of chain cables, each cable composed of three chains.

In 1794 a bridge was built near Portsmouth, N. H., 2,362 feet long, in the center of which was an arch span of 244 feet 6 inches, and with a rise of only 27 feet 4 inches; quite a masterly piece of architecture.

In 1805 a bridge of three spans 163 feet clear was built over the Delaware River, at Easton, Pa. It was covered in from the weather and is still in use and in good condition.

Many bridges of considerable magnitude were built up to 1820, but were arched structures.

In 1820 Ethiel Town patented his lattice bridge, which was the first marked step toward bridges of the modern truss form. A great many of these were built up to spans of 220 feet, both for highway and railroad puposes; and some are still in existence. The absence of all bolts, straps, and rods, and simplicity of connecting together the parts, made this a cheap and popular structure.

The next step towards simplicity and concentration of parts was the Long Truss, in which iron did not necessarily enter. Many of these were built, but it did not become widely popular.

Each of these trusses were combined with arches oftentimes, for the longer spans. The next important advance in style of truss was made in 1840, when William Howe patented the truss which was the basis of the present Howe Truss bridge. In his truss the vertical members were in tension and made of iron rods, all the rest of the members being of wood.

In 1844 the Pratt Truss was patented. It differed from the Howe Truss in that the vertical members were in compression and made of wood and the inclined members were in tension and made of iron. This did not become as popular as the Howe Truss on account of the greater quantity of the, then, more expensive material, wrought iron, being required.

The development of wooden bridges was entirely empirical, the proportioning of them being determined either from the result of previous failure or from the study of models. An advance was shown, however, towards simplicity of form and construction, and in the matter of details.

The first iron truss bridge built is believed to be the one

erected over the Erie Canal, at Frankfort, N. Y., in 1840. The truss was a combination of the truss and suspension principle, and was formed of seven cast iron sections, about 11 feet long and 7 feet deep, bolted together, each section consisting of an upper chord, a pair of diagonal braces, and half of a hollow cylindrical post at each end, to the bottom of which were bolted wooden transverse floor beams. Two wrought iron suspension rods one and one-half inches round, were attached to the tops of the end posts, and sagging in a parabolic curve passed underneath the two central floor beams supporting them, and by means of lugs at proper elevations, were attached to the other posts.

In 1840 Squire Whipple built his first iron bridge, a bowstring truss, the compression members being cast iron and the tension members wrought iron. A good many of these were built with spans from 50 to 100 feet, and some up to 180 feet.

In 1846 Frederick Harbach patented an iron Howe truss. The top chord and braces consisting of cast iron hollow cylinders in pairs, and the lower chord and vertical rods of wrought iron. The lower chord being two cylinders of boiler iron riveted together as continuous tubes. The chords and braces were connected by cast iron saddles.

In 1847–50 a number of bridges were built for the New York and Harlem, Erie and other railroads, having parallel chords and multiple systems of vertical posts and diagonal ties. The compression members being cast iron, and the tension members flat bars of wrought iron. The members were bolted together and wedges inserted at top of each post to tighten up the systems.

The failure of one of these bridges on the Erie Railroad, in 1850, at about the same time as the failure of one in England over the River Dee, led the officials of the road to the belief that iron bridges were untrustworthy, and they directed that all the iron bridges on the road be removed and replaced by wooden ones.

The first impulse to the general adoption of iron for railroad bridges was given by Benjamin H. Latrobe, Chief Engineer of the B. & O. Railroad, when he decided to use iron in

all the new bridges upon an extension from Cumberland to Wheeling.

From 1851 on, a good many bridges were built on the Bollman and Fink plan, using both cast and wrought iron in them.

In 1852 Squire Whipple built a double intersection Pratt Truss on the Rensselaer and Saratoga Railroad, near Troy, N. Y., of 146 feet clear span, which was proportioned for a rolling load of only one ton per lineal foot.

In 1858–59 a Whipple Murphy bridge of 165 feet clear span was built at Phillipsburg, N. J., which was the first span to be pin connected throughout.

In 1861 Mr. J. H. Linville built a bridge for the Pennsylvania Railroad, in which was used for the first time wide-forged eye bars and wrought iron posts.

In 1863 John W. Murphy built a bridge for the Lehigh Valley Railroad at Mauch Chunk, in which he used wrought iron for both posts and top chord sections. This was probably the first American bridge in which all the tension and compression members were of wrought iron. In this were used, however, cast iron joint blocks and pedestals.

In 1865, S. S. Post built his first bridge, known as the Post Truss, for the Erie Railroad. A large number of these bridges were built up to 1880, due, in part, to their apparent stiffness.

In 1859, Mr. Howard Carroll commenced building riveted lattice bridges for the N. Y. C. Railroad, in spans from 40 to 90 feet, and being well proportioned as to strength of parts and details of connection, soon took the preference on the Central and neighboring systems. The spans were afterward extended up to 180 feet.

The era of long span bridges dates from 1863-4, at which time a span of 320 feet was built over the Ohio River at Steubenville. This was proportioned for a load of 3,000 pounds per lineal foot of track, and was made of cast and wrought iron.

In 1872, the Newport and Cincinnati bridge was built, one span being 420 feet.

In 1868-74, James B. Eads built the bridge at St. Louis over the Mississippi River, consisting of two arches of 502 and 520 feet clear span each.

In 1876, the Cincinnati Southern bridge over the Ohio was built, having a channel span of 519 feet, the longest truss span ever built to that date.

The channel span of the Kentucky Central Railway, at Cincinnati, 550 feet, was the longest independent truss bridge up to 1889.

The first important iron cantilever bridge was the Kentucky River bridge, built by C. Shaler Smith in 1876-77, consisting of three spans of 375 feet each. Next was the Minnehaha bridge over the Mississippi, at St. Paul, built in 1879-80. Third was the Niagara Cantilever on the M. C. Railroad, designed by C. C. Schneider, and built in 1883. This bridge, which has been under my personal inspection for the last four years, is a double track structure, consisting of a single span 495 feet centre to centre of towers, and it is approximately 250 feet from base of rail to the water in gorge below. We have lately had to adopt measures to prevent a rusting of the iron caused by brine dripping on it from refrigerator cars. A train of these cars stand upon the bridge while the Custom Officers are making their inspection, and in warm weather considerable brine drips from them. Paint proved to be of little avail in protecting the iron, so we were obliged to adopt means to keep the brine from coming in contact with the iron at all. This was done by filling in between the ties with a petroleum product called Byerlyte, which drained the brine towards the center of the bridge, where it was collected in gutters and carried off.

The cantilever of largest magnitude is the Poughkeepsie bridge, built in 1888.

The advantages of the cantilever are the ease and economy of erection of long spans over deep gorges or rivers, where the waterway cannot be obstructed.

The combination bridge, a type holding a place between the wooden bridge and the all iron, was used a good deal in the south and west, being cheaper than the wooden bridge. Its adoption was governed chiefly by the financial ability and policy of the corporation for whom they were built.

The iron viaduct, a type of bridge holding an important

place among bridge structures, had its origin about 1868 in the construction of the Bullock Pen Viaduct, on the Cincinnati and Louisville Short line—a structure 470 feet long and 60 feet high. The first step toward the use of iron in viaducts was in 1851, when iron rods were used for longitudinal bracing in wooden trestles to hold the bents together. Next came the gradual use of cast iron for all compression parts until 1868, when we had the all iron structure mentioned above. The general uniformity in present designs dates from about 1878. The distinctive features in them at present being due chiefly to economical considerations.

As I mentioned before, the early wooden bridges and some of the iron ones were not designed or proportioned on any very correct theory. They were largely empirical structures. As an illustration: Mr. Kirkwood, an able engineer of the time, wrote—"The heavy locomotives used in the freight traffic of railroads and the great speed of express passenger trains, render massive strength in all railroad bridge structures essential. The many bridges which have been strengthened since they were built, and the many which have had to be removed and replaced by stronger structures, sufficiently attests the mistaken economy of erecting light and cheap frame bridges. The blind confidence which the best of carpenters are apt to have in the raw material of their trade and in the rude geometry of its usual combinations, has rendered them unsafe guides to engineers in the planning of bridge trusses involving irregular and shifting strains, with which their general practice cannot make them familiar. Hence it is that even now the engineer will always find it not merely a safe but a necessary rule to make his bridge trusses heavier and stronger than the most intelligent professional carpenter of his acquaintance is likely to consider necessary." So the best the engineer could do was to make his bridges stronger on the basis of past experience.

The first attempt to analyze the strains in bridge trusses was by Squire Whipple, in 1847, but the results were not widely known for some time.

The use of one ton per foot, uniform load for designing

all parts of a railroad bridge, was in general use up to 1860, and later in many instances. In 1870, a heavier uniform load began to be used to design the floor system, than the truss, and in 1876, the use of actual concentrated loads, as existing in a train, were specified by Mr. Bouscaren for the Cincinnati Southern Bridge, at Cincinnati. Rolling loads have steadily increased in weight, and at the present time the M. C. Railroad's, which are among the heaviest loads specified, are two engines coupled, each weighing 123 tons, followed by a uniform train load of 4,000 pounds per lineal foot of track. In our practice we add a percentage to the above induced strains for all spans under 100 feet, determined by the formula ($1\frac{1}{3}$—L÷300) in which L is the length of span in feet.

Highway bridges should be designed to carry, in addition to their own weight, 100 pounds per square foot of floor surface, a traction engine weighing 11 tons, or any other especially heavy load they may have to carry. The 11 ton traction engine, which has recently been put upon the market in this State, is the heaviest single load, to my knowledge, that the ordinary highway bridge will be required to carry. We have recently had to strengthen the floors in our overhead bridges, to make them safe for this loading. The engine will generally govern in designing the floor of a bridge, and 100 pounds per square foot of floor surface for the main truss members.

The advent of iron construction involving the use of a more expensive material, compelled a better consideration of the relation of the parts of a truss to the duties to be performed. The investigation made during the building of the St. Louis bridge, into the strength and other properties of materials of construction, and the testing of full sized members and their detail connections, gave a great advance in knowledge of these matters. Comparatively little was known before this, but the deductions from these tests awakened a desire for a better knowledge of the form and proportions of bridge members, and as a result most of our large bridge companies to-day have testing machines to test sample pieces or full size material. Every railroad company that is now abreast with the times, and is cognizant of the value of good material over that which

may not be, has its bridge material inspected at the mill, both chemically and physically. The inspection should be followed through very carefully, all of the material in a bridge. It is not sufficient that one or two melts out of several should be tested and conclude that the others will be like these. Every melt should be tested, and then it is known as thoroughly as is possible, the exact quality of all the material. Without this thoroughness a great deal of the advantage of inspection is practically lost, and any laxity in this respect would have its effect in the deliberations of a jury.

Steel has lately supplanted wrought iron for use in bridges. Its cost is less than that of iron and it is stronger. Compared with wrought iron, soft steel has 15% higher ultimate strength, 20 to 25% higher elastic limit, and 50 to 70% greater ductility. It has equal strength, ductility and bending qualities, lengthwise and crosswise of the material, while wrought iron strained across the grain has little strength and ductility and will not bend. Further, steel has no fiber and consequently less disposition to tear and pull out, and is capable of a finer finish. The Carnegie Mills have stopped making wrought iron, their exclusive output being steel. It can be obtained in three general grades, the soft, medium and high steel. So that the different members of a bridge can be made of a grade most suitable for the work to be done, according to the ideas of the engineer.

Steel is made by two general processes, the Bessemer and open-hearth. The Bessemer output is considerably the largest, but the open-hearth process is considered by a great many to produce a more uniform and better product. Many of the leading engineers of the day will not permit the use of Bessemer steel in bridges at all, and Mr. Waddell goes so far as to specify that any attempt by manufacturers to substitute Bessemer steel for open-hearth will be sufficient cause for cancelling a contract. The advantage of open-hearth steel is that it is a more uniform product, and so less liable to have any excess of the objectionable element phosphorus. It has proved a more reliable material, for in the case of failure, sometimes due to shop manipulation, sometimes to shock when under stress,

and sometimes from unaccountable or mysterious reasons, it has generally been traced to the Bessemer product.

Phosphorus is the particularly objective element in steel, its presence in too large quantities making the steel very brittle and treacherous. It should not be allowed to exceed .08% in amount. The other elements, carbon, silicon, sulphur, etc., may vary in amount with less effect. Some engineers, however, give limits for these elements, but by specifying a certain ultimate strength, elastic limit, % of elongation, and reduction of area, with a maximum phosphorus limit, a good steel can be obtained, leaving the other elements to the option of the manufacturer. So in getting steel for bridge purposes, the method of manufactnre should be specified, the chemical composition to a certain extent, and the physical properties.

The open-hearth steel can hardly be discerned from the Bessemer, from a surface inspection, and consequently the first duty of the inspector is to see that the open-hearth product is obtained.

In the manufacture of steel in the bridge shop, care should be exercised to have about three-sixteenths of an inch of metal removed from all sheared edges. In shearing and punching, the steel undergoes a small injury; the surface is compressed or displaced next to the cutting tool, reducing the area and having the effect of reducing the ductility and ultimate tensile strength. This injury is less in soft steel which is not more than three-eighths of an inch thick but increases as the steel becomes thicker and with the higher grades of steel. Steel over three-fourths of an inch thick had best be drilled, as the injury from punching becomes too extended. Steel under three-fourths of an inch thick should be punched one-fourth of an inch in diameter less than the finished hole, and reamed to full size. Tests have been made showing that a steel bar three inches by five-eighths of an inch is reduced about 15 per cent. in strength by punching alone. But by punching and reaming, as indicated above, the strength remained hardly impaired. No advantage is gained in the medium thickness of steel by drilling. The punching and reaming showing up equally well, and is cheaper.

The painting of bridges to protect them from rusting, is a subject which has not been given the careful attention in the past, which is warranted. Iron exposed to the air and moisture, will rust or oxidize, and if not protected would rapidly lose its strength; much more rapidly in some localities than others. The first requisite of good painting is to have a clean and rustless surface. If paint is put on over an imperfectly cleaned surface or rust, moisture will get in, the paint will swell and burst, and oxidation go on. It is a difficult matter to have iron properly cleaned in the shop, and a certain amount of rusting will take place while the iron is being shipped from the mill to the bridge shop, it oftentimes being stored out of doors for some time. To obviate this I would recommend that iron be given a coat of pure raw linseed oil before it leaves the rolling mill. This will protect it up to the time of manufacture at the bridge shop. After manufacture it should be retouched with oil to cover rivet heads and parts where the oil has been rubbed off. And after erection in the field give it two good coats of paint. This painting had best be done by the corporation for whom the bridge is built, and by day labor, not contract. The advantage of using raw oil instead of boiled is that you may be sure of a pure article. The advantage of oil over paint for a first coat, is that rust and scale cannot be concealed from view, so that when you come to paint the bridge yourself, you may be ensured of a perfect surface for the paint to adhere to.

An iron bridge properly protected would probably last forever, while one which was carelessly looked after, might not last twenty-five years,

The life of a railroad bridge, so far, has been determined by its ability to carry the increased loads over those for which it was designed. The question comes up in our office very often, is such a bridge, built a number of years ago, safe for our present heavy trains?

With regard to paints, red lead and oxide of iron are the leading ones. Each of them have many advocates, but I think the consensus of opinion favors red lead. We have just finished painting the iron bridges on the entire system of the M. C. Railroad, and used the following mixture: Sixty-four pounds

dry red lead, 12½ pounds graphite paste (manufactured by the Detroit Graphite Manufacturing Company), and 3¼ gallons of raw linseed oil. Figuring the lead at 5½ cents per pound, the graphite at 8 cents per pound, and the oil at 55 cents per gallon, will bring the cost of this mixture to $6.44, or a little over $1 per gallon. This is more expensive than the oxide of iron, but will cover more surface. We mix the paint as it is used, as we are sure thereby of getting pure ingredients, and red lead should be applied before it has stood very long after mixing. Mr. Bouscaren states that under favorable conditions oxide of iron will last three years, and that red lead will last six years.

Most all of the old type of bridges are things of the past. Present practice is pretty uniform as regards the type of structure for different spans. Our practice is to use riveted plate girders or rolled beams for spans under 90 feet, riveted lattice bridges for spans between 90 feet and 130 feet, and pin connected trusses for spans over 130 feet. The plate girder bridge is the most expensive, but is the most popular structure, and the best one, on account of its rigidity, and the absence of parts to get out of order. It is particularly desirable on railroads, as it presents no impediment to the passage of loaded cars, which the through truss does. The question is constantly coming up, can a car with a certain load clear the bridges safely on a certain part of the road? Besides, the danger from derailed trains is reduced to a minimum, and the danger of projections from loaded cars knocking out some of the members of a truss, entirely done away with. It is our practice to build several short spans of girders, in preference to one long span, if the waterway can be obstructed to the extent of placing piers in it. The lattice bridge is cheaper than the girder, and its rigidity especially commends it in preference to the pin truss. The pin connected truss is cheapest for all spans, and for the longer spans is sufficiently rigid to compare favorably with the riveted truss.

Wooden floors are beginning to be discountenanced in first-class bridges, their places being taken by the iron and ballast floor. There are several designs of these in use upon different roads, but I think the one designed by Benjamin Douglas,

Bridge Engineer of the M. C. Railroad, superior to other designs, in that the ballast, which is one foot of gravel, does not come in contact with any part of the bridge which undergoes stress. This floor is made by placing I beams crosswise of the bridge, one foot apart, the entire length. On top of these beams is a solid flooring of three-eighth inch plate to hold the ballast. The latter being confined on the sides by a line of angle iron. A coat of Byerlyte about one-fourth inch thick is put on the iron plate to prevent it from rusting. The cost of this floor is about $6.50 per lineal foot more than the wooden floor, as we build them. The advantages of this floor are, less danger from fire, the maintenance of a smoother track, the dispersion of forces due to power brakes, through the ballast, and the approach to static in mechanical effect of imposed loads.

The present bridge should be designed with reference to the future and should be liberal in the quantity of material used and judicious in its selection and manufacture. The bridge, besides being designed for actual work required to do, should be designed with forethought for what it might have to do in case of derailment or other emergency. To obtain these results, the bridge engineer acting for the corporation for whom the bridge is built, is a necessity. The competition on bridge work at the present time is so fierce that the engineer of a bridge company is allowed no latitude and is forced to keep his design down to as low limits as his intelligence and shrewdness will furnish him the means so to do. If he does not, he will not get contracts and his company will not be long in need of his services. Besides proportioning the main members to as low an amount as allowable, the detail connections can be sacrificed to a very undesirable amount, when good strong concentric connections could just as well be obtained. It is just as important to have an inspector follow the work through the shop and see that first-class workmanship is obtained as it is for you to watch an architect or builder in case he was building a house for you. I am sure that any of you would not allow an architect or builder to go ahead and build a first-class house for you for a certain amount of money, without giving your careful attention to every detail. This is of more im-

portance with the bridge, to ensure safety, as near as is possible, to the hundreds of human lives which daily have to make use of them.

Mr. Hodgman.—Mr. Duncan, in his paper, was speaking of the effect upon the iron of punching or drilling holes. Does the addition of a small percentage of aluminum to the iron or steel make any difference with the drilling qualities?

Mr. Duncan.—I am not very well posted on that subject, because I don't think it is a question that has come up in a practical way, but I should think that the effect of the use of aluminum would be to lessen that difficulty, because it makes a softer quality of steel. I understand that aluminum is being extensively used in the manufacture of iron and steel. It has not been used in bridge engineering iron—structural iron, to my knowledge. I have heard it talked of for castings, but I don't know of its being used.

Mr. Dryshall.—It is used in castings. It makes better castings, but I never heard of it as used in steel.

Q. What percentage brings the best results?

A. I don't know—just a small percentage.

Mr. Pashby.—I have been told that it is a practice of bridge companies, in bidding on a contract, to put all the bids at a sufficiently high figure so that the successful man can whack up with the unsuccessful bidders. How that may be, I can't say. I hope it isn't so. As the speaker has said, bridge building is a science, and the average man who has to deal with the contractor, is utterly incompetent to deal with him. He knows nothing whatever about determining the stress in the different members of a bridge. Now may not this condition of affairs be remedied in some such manner as this:

May not the regents of the University and the State Board of Agriculture be requested to authorize members of the engineering departments in those two institutions to undertake the inspection of plans submitted, and the inspection of the bridges, if necessary?

We have a precedent for this in the matter of fertilizers. As some of you know, if a man wishes to retail a fertilizer in

this state for more than $10.00 per ton, he must pay a license of $20.00, and some sample of his wares, purchased in the general market, is analyzed by the chemist at the experiment station at Lansing.

Now will it not be a parallel case to have plans and specifications submitted by the Bridge Companies, inspected by the engineers at these two schools, who are competent to do the work? At the present time, those departments are worked to their full capacity, but it might be necessary for a time that this work be borne by the present force, as it is not likely that the boards having the contracts to let would take advantage of any such offer, and perhaps the work could be borne by the present force, but in the event of their being crowded, the State could well afford to pay an engineer to make these examinations. It is well known that the local boards are very much averse to paying an engineer for any such work as that —they don't see, as a general thing, the necessity of making a very heavy outlay, but I believe if some such thing were offered to them, free, that many would take advantage of it. I am strengthened in that opinion by a talk which I had with a highway commissioner in the southern part of the state a few weeks ago. I determined to start an investigation of the way in which bridge companies are dealing with the Highway Commissioners throughout the State. The only man I have talked with, up to the present time, was a Mr. Goodrich, of Gentreville, St. Joseph County, and during the last summer, in that Township, two bridges have been built.

I asked Mr. Goodrich to let me take whatever plans, specifications and data he might have on these bridges—left him by the companies who put them in. He said he would be very glad to let me take them—and what I got, lies on the floor by my desk at the college. They consist of two blue prints, and it seems as if the company had studiously avoided putting on them sufficient data to determine what the bridge was good for. In one case the length of span had been omitted, and also the capacity of the bridge. The factor of safety was omitted in both cases. On the other, the height of the spans was omitted, although the length of the spans and

the capacity is supposed to be given, 125 pounds per square foot.

Now it seems to me, that the next best thing to having an inspector to look over the bridge during the process of construction, as suggested, would be to have the companies leave sufficient data so that these details may be inspected afterwards.

As an illustration of what may be done by the companies, I had the privilege of reading a contract that was made with a Board of Commissioners in New York some time ago, in which they had inserted this little, innocent clause: "The Bridge Company reserves the right to change the form of cross section of any member, if they keep the area," or words to that effect. That binds the Board of Commissioners—places them completely at the mercy of the company having the bridge to construct.

Take compression members—change the form of cross-section and they may be utterly worthless. These are extreme cases, yet it seems to me that the Society would do a good thing for the people of the State of Michigan if they could inaugurate some means of giving the Highway Commissioners a fair chance with the Bridge Companies.

Mr. Sears.—There may be profit in it, to the Highway Commissioners; perhaps they will object.

The President.—It has always seemed to me that the farmers had that matter all in their own hands. There are plenty of competent engineers who would be glad to render their services for a very modest amount—to pass judgment on the sufficiency of any plan, and I find that in villages, and small communities, fully as poor as a township of farmers are generally, when they come to put in a water works or electric light plant, they uniformly call upon someone with sufficient knowledge to put them in possession of the data, so that they can enter into a contract intelligently, so that the ends of justice will be fully met. In the matter of bridges, which it seems to me is considerably more difficult work than the preparation of plans for water works, and a matter harder for the average man to apprehend, they hire some fellow, or elect him, as Highway Commissioner, and pay him $1.50 a day to go

and take entire charge of passing upon the sufficiency of a bridge plan. In this state, the Town Board and the Commissioner together, can, by the expenditure of a modest sum, get, in a good many towns in this state, an engineer to pass upon it. While the matter of submitting it to the University and Agricultural College professors would be a safe one, yet it would be drifting into a form of paternalism, which I don't believe is a good policy to adopt in our form of society and government. The object of dividing into townships, is to enable people to control their own local affairs.

Mr. Douglass.—I don't, myself, believe in the State taking much charge in the construction of bridges, although I wish we could educate the farmers and the township authorities sufficiently to make them understand that it was profitable to hire an engineer.

Mr. Granville.—It is not possible for an honest company to do business with these small towns; if a company wants to build a bridge in a small town, it has got to do it cheaply. While I don't believe in cheating, still it drives the good companies out of business, and I think the farmers themselves are to blame.

Q. If you were going to settle the blame for this whole matter somewhere, where would you put it?

A. It rests on the farmer. If they don't insist on having a good article, they won't get it. The trouble is, they think if an engineer charges $25.00 for passing his judgment on a matter, that he is cheating them, and they would just as soon be cheated by the bridge company as by the engineer.

Mr. Rogers.—I have heard of a plan that struck me as being very good, and it will perhaps put bridge companies on their guard. I don't suppose that we can expect that the farmers will, much before the millenium, see fit to hire an engineer sufficiently able to pass upon the bridge when they build it, but I think if there were a law requiring every company putting up a bridge anywhere in the State, to file detail plans of that bridge with some officer in the State, even if they were not examined at the time, and then if anything happened to the bridge and it was shown by the examination of these

plans by an expert that they were not up to specifications,——

Col. Muenscher.—That leaves it for the autopsy.

Mr. Rogers.—Yes, but bridge companies might be afraid of the autopsy.

Mr. Hodgman.—I was going to suggest another thing, that is not original. The State of Michigan undertakes to say that if an insurance company does business in this State they must show that they are sound, and then if anything is wrong, it must be made right. They must put up a guarantee. What sort of a scheme would it be to make the bridge companies put up a similar guarantee? Let the bridge companies make their own designs, and say nothing about it. All we ask them is to say, "We will put you up such and such a bridge, and we guarantee that for such a time, that bridge will be good and what we represent it to be." That relieves the whole question, places the whole responsibility with the bridge company to do what they agree.

Mr. Douglass.—Any bridge company will guarantee its bridge, because it is reasonably certain it won't get the load designed for it, and, in fact, there are very few bridges in this State which would stand a crowd of people on them, I think, and the chances of a bridge company having to pay damages from a bridge falling down are so slight, that it would take the contract and build them just the same, and when a crowd of people did get on, they would go down and the people would be killed.

The President.—The sale of a bridge involves the same commercial principles as the sale of a suit of clothes does, and it is supposed that both parties shall know their business. If the purchaser does not know what constitutes a good bridge, it is his business to find out, and if he puts up a bridge that is unsafe, it would be well enough to settle the blame on the Township officers. They are paying the money out; you can't get two dollars for one dollar, and they are the responsible parties. That is where the responsibility ought to be placed, and not on the bridge company, who are there with their skinning knives, in competition with each other, and these

people invite the skinning. If a farmer is skinned through his lack of good horse sense, it is his own fault.

Mr. ————.—That would answer very well if it were simply a question of dollars and cents, but the lives of the public are being exposed, by these poor substitutes for bridges, and it seems to me there ought to be some sort of control exercised, as over insurance matters, infectious diseases, etc., anything that threatens the life of the public.

I like Prof. Pashby's proposition very well. In some States, I think they have State Engineers, whose business it is to pass upon bridge plans, and that project was at one time proposed in this State—the appointment of an engineer, whose business it should be to examine all plans before acted upon; but it is not simply the adoption of the correct plan. That would be all right, but you must follow the thing out—see if the plan is complied with, and the right sort of material put in. Now the ordinary engineer, though he may be competent to pass upon the adequacy of the plans for a bridge, cannot, as a general thing, determine whether the material is good or not. It must be followed up at the rolling mill, and the bridge works —the workmanship and quality of material must be tested at the time. After it gets on the ground, to be put into the bridge, the local engineer cannot do anything about it. He can only see that he has the right size.

Mr. Hodgman.—That raises the question in my mind, how far inspection inspects, in the manufacture of iron. In the first place, how many engineers are competent to make such an inspection, and in the second place, suppose they are, how far can they carry it out? I have been led to believe, in connection with some of the developments in armor work, where they attempt rigid inspection, for the United States, that it is a question whether you can carry out a system of inspection that will be thoroughly satisfactory.

Mr. Douglass.—I think the inspection at the mills is very satisfactory; at some of the smaller mills, there is perhaps some cheating done; at the larger mills, I am pretty confident there is not. They cannot do it. They are turning out an immense amount of steel, and it is all stamped with the mold

numbers, and these molds are tested, and they haven't time to stop and substitute; it would cost more to substitute poor material for the good, than it would amount to. In the armor plate—that was inspected by men who didn't know much about it, and there was a great deal at stake.

Mr. Hodgman.—The discussion in connection with that was what I had reference to—as to the practicability of carrying out a thorough system of inspection in those large iron works.

Mr. Douglass.—You must depend partly on the maker, and the fact that they cannot very well substitute. They stamp all the material with the mold numbers, as it comes from the mill. This is done by a man who does not know what it is or where it is going, and they are not likely to attempt to substitute, for it won't pay, even supposing they were willing to do it.

Col. Muencher.—I don't think the difficulty lies so much in the rolling mills, because they have their reputations to sustain, but these "tin" bridge companies don't care much for their reputations.

Mr. Douglass.—I guess some of the rolling mills don't care much either; some will cheat you if they can, but then there are a good many that won't, and as I say, the larger ones can't very well, except that they might substitute a piece occasionally. In the bulk they can't substitute, because it would cost more.

As to inspection by the State; I think if the State is to do anything, it would be better to have an engineer on purpose for that—an engineering department, and charge the cost to the Township authorities where the bridge was built, and they would have to make it compulsory on the Township authorities to employ a competent engineer or have the work done by the State engineer and be charged for it.

Mr. Appleton.—Wouldn't it work about like our banking commissioner, who is to prevent all banks from breaking, and the insurance commissioner, who guarantees that the insurance companies shall all keep the faith?

A. It would depend largely on the engineer; if you could eliminate politics, it would be all right.

Mr. Duncan.—In connection with my paper, I wish to state something about the erection of bridges; in erecting our new bridges in place of old ones, we do it very rapidly, erecting the new bridge on false work, one side of the old bridge, and if the old bridge is a wooden trestle construction, we get the new bridge up in proper shape, with the ties and rails on, and get the use of the track for perhaps half an hour or so, and throw out the old bridge. We have made the change of a span 150 feet long, in 27 minutes, and it has been only thirty-five minutes between the actual passage of a train of the old bridge and the new one. This is necessary, in order not to delay traffic.

The President called upon Mr. Granville to speak.

Mr. Granville.—I unfortunately did not hear that paper read, and have heard but little of the discussion. I hardly know what you want to hear from me, or what I can say.

The President.—We want a cure for the present system of bridge building—we want honest work.

Mr. Granville.—I don't know that I care to give away any of the secrets of the trade, but it strikes me that to secure the best results, the engineer, I don't mean a general engineer, but a man who is competent to design a bridge, should be employed for all bridges of any importance, at any rate, to prepare plans for these different townships or counties or cities, or whoever is going to construct the bridge, and proposals should be received upon that one plan, from all the companies competing for the work. Usually they advertise for proposals, and each company submits its own designs It is a very nice thing for the bridge companies, because it affords an elegant opportunity to do some leg pulling, and very frequently it enables a man who is somewhere near the top to pull the contract, although he may not have a design as worthy as the man who has bid lower, but on account of his nice show plan, and ability to talk, he succeeds in pulling the contract his way, while there would be less chance of doing that if all were bidding on the same design, and that a good one, prepared by someone not connected with the contracting firms.

Mr. Elder.—A certain city in this State built a bridge a

few years ago. It was a 50 foot span, and 35 feet wide, and in asking for bids, the only condition made was that it should come up to Cooper's specifications for class A Highway Bridge, the design being left to the company, and the bid accepted was for a pony truss; the contract was made out so that the company should be held rigidly to Cooper's specifications, and the plans submitted were looked over by a general engineer, and I believe he also went to the works and examined into the process; the bridge was found to be all right, except five or six points which were changed, and it was accepted in every point, except that the floor was not quite up to the standard, and $50.00 was held back.

The contract price for the bridge was $2,250 for the span. The amount of iron in the bridge was figured, and the cost seemed rather high. It was, however, the lowest bid, and was accepted. Afterwards it was hinted that it was rather higher than it ought to have been, and it was found that the bridge could have been built for $1,700 or $1,800. Now the question was, did the representative of the bridge company, who made that contract, with the men who let it, all gathered together at one time, did he make a donation? If so, how can it be brought about that a contract can be bid for without allowing them to make these donations?

A. They can do it by hiring an engineer who is posted in the business well enough to know the commercial price of the materials.

Mr. Riggs.—It seems to me that the whole of this matter is the fact that the people are not willing to trust the engineer. If they have a case of typhoid fever, they trust a doctor, but the majority of common councils want to do their own engineering, or a large part of it. The specialty of bridge engineering is entirely separate and distinct from general engineering, and the man who is in general practice is neither competent or qualified, as a general rule, to pass with thorough understanding on matters of this sort. It seems to me that in some way or other, a thoroughly competent bridge engineer, a specialist, should be selected. The matter of the preparation of plans and specifications should be left to him. He should

ask for and receive bids, and submit the bids or a synopsis of them, to the proper authorities with a recommendation. He should name the inspector, and in that connection, it is immaterial whether the contractor shall pay for this work, or the people, or the company, but it is proper and right that they should name their own inspector and have him report to them, but if the whole thing is left to one man, and he prepared the plans and specifications, if he is a competent man, the chances are that the work will be better done, and then the people will know where to place the responsibility; that is the feature that now it is impossible to locate. If you have a bridge builder, you don't know whether to blame the contractor, the engineer or the trustees or councils, or the authorities representing the people.

It seems to me simply a matter of the competence of the engineer, and the recognition of the fact that bridge engineering is a specialty, entirely separate from other classes of engineering work.

Col. Muencher.—I think that idea is correct. To tell the truth, there isn't one person out of ten competent to pass judgment upon bridges. A man must make it a very careful study, to be able to test the correctness of the plan, and as for making a plan himself, there is hardly one man in ten who can do it. He must be familiar with the method of calculating strains, he must be practical, or he will get in sizes that are not marketable and compel the making of new patterns and add a great deal to the expense of the bridge. A man ought to be specially qualified for bridge engineering before he is allowed to pass upon the adequacy of plans.

Mr. Granville.—It is hardly fair to condemn bridge companies too severely for some of their practices. Of course there are many things they do practice that are to be condemned, but you must take a great deal into consideration.

You would be surprised, those of you who have not run against the thing, the amount of corruption there is among the ordinary country officials; it is, in many cases, impossible to do business or make a contract without first doing a little business with some of these farmers, and often, it does not take a great

deal to do it, either. Ten dollars goes a long ways. There is this element to be met with in this kind of work, and bridge contracting is, I think, peculiar to itself. I have done contracting in a number of different lines, and since I have gone somewhat into the line of bridge contracting, I have gained an experience which I never had anticipated, and struck things which were way beyond anything I had met with in other lines of contracting.

Mr. Douglass.—I think there is no doubt about the remedy —the proper remedy for this trouble. I think Mr. Riggs has stated the medicine very well, but how are you going to administer it?

Mr. Granville.—The Engineering News of a few weeks ago discussed this point which our Kalamazoo friend brought up. How are you going to stop pooling among bridge men? They, it seems to me, take a sensible view of the question, and if any of you are interested in the matter, I would refer you to your back numbers of the Engineering News. It is there discussed in a very rational manner.

Mr. Sears.—I think the thing can be simplified, if the counties as a community, would change their system. In this county we have fifty supervisors. A few months ago we wanted an appropriation of $500 to make some repairs on the Court House. We had to call a three days' session to get permission to raise that $500. That cost $518 to allow an expenditure of $500. Now if that system could be changed, and that force reduced to five competent men, they could do the work of this county in less time than the fifty, and you might include among them, one competent engineer. I think these bridges should be taken out of the hands of the Township officers.

Motion made, supported and unanimously carried, to extend a vote of thanks to Mr. Duncan for his paper.

EFFECT OF FREEZING UPON CEMENT.

BY E. W. MUENSCHER, C. E.

The Committee which was appointed at the last Annual Meeting of the Michigan Engineering Society, for the purpose of investigating the effect of freezing upon cement, being composed of gentlemen scattered all over the State, the manifest impracticability of bringing them together for consultation has suggested the idea that each member should make his own investigations and present his own conclusions. While, therefore, the writer, as Chairman of the Committee, has felt it his duty to the Society to investigate the subject more thoroughly than he might otherwise have done, he desires it understood that no other member of the committee is responsible for anything that he might say.

The subject, of the effect of frost upon cement mortar and concrete, is one which is of great interest to every Civil Engineer and practical Mason, and yet it is one that is very imperfectly understood. This is, no doubt, owing to the fact that but few engineers have ever been called upon to deal practically with the problem. For many years there has been a very general impression that frost is injurious, and for that reason the profession, almost without exception, has endeavored to avoid all masonry construction during freezing weather. It is a very common thing to find in specifications for masonry a provision that no work shall be done between the months of November and April, or some other equivalent period, the only object of this provision being evidently to avoid the effects of frost.

That this provision is a wise one, when circumstances permit its enforcement, there can be no question, for all experience confirms the correctness of the general impression of the injurious effects of frost, at least in some degree, and it is never good policy to run unnecessary risks. In the great

majority of cases it is perfectly practicable to suspend work during the winter, and some of the prominent engineers in the country, in reply to the writer's enquiries as to their experience, have stated that this has been their invariable practice. There are numerous cases, however, in which this would be impracticable. On our navigable canals most repairs and new work in masonry cannot be done without drawing off the water, and must therefore be postponed until after the close of navigation. Many manufacturing establishments in the Northern States make all their repairs and extensions during the winter, because during the rest of the year they are operated to the limit of their capacity, often day and night, and cannot be shut down for repairs without great loss.

In all such cases, where the construction of masonry in freezing weather cannot be avoided, it is of great importance to know: First, how frost affects cement; second, what is the rationale of this effect; third, how this effect can be avoided or remedied. These are questions which can only be answered by experiment, and yet, up to a very recent period, no such experiments had been made, unless we regard as an exception the practice of putting salt in the water with which mortar to be used in cold weather was mixed, which had become quite common years ago. So long ago as 1856, the writer finds in his notes of Prof. W. M. Gillespie's lectures to the Engineering classes of Union College, the following remark:—"If common salt be mixed with cement, say a peck to a bushel, the mortar made with that may be used for laying masonry in freezing weather. This is practical on the canal work." This was all that the Professor told us on the subject, and most likely it was all that he knew.

Within the past few years, however, this subject has been exciting much interest, and a number of experiments have been made which have thrown much light upon points which had previously been quite obscure and imperfectly understood. The writer feels that he cannot do any better service to this society than to lay before it the results of these experiments, so far as they have come within his knowledge.

The first series to which your attention will be invited was

conducted during the winters of 1890-1891 and 1891-1892, by the Cement Committee of the Austrian Society of Engineers and Architects. In response to a request for advice, from the Contractors for the construction of a new theatre at Zurich, Switzerland, in the prosecution of which it was necessary to lay some masonry in winter, the reports of these experiments were published in the Society Journal for February 16, 1894, and a quite full translation of the report can be found in the Engineering Record, Vol. XXIX, Page 251.

For the benefit of those members of this society to whom none of these means of information are accessible, we give the substance of this report.

"The experiments were made in two ways, the first with brick masonry and the second with rubble masonry, using stone of two kinds, in order to determine whether there was any difference between materials which were unlike hydroscopically." It is important to note that "the materials used were dry and free from snow and ice, and the mortar was mixed as stiff as possible," a condition not always met with in practice. The separate pieces of brick wall tested were about 1 meter long, 2 meters high and 12 inches thick and was made with lime, Roman cement, Portland cement, a mixture of lime and Portland cement, and Slag cement. The mortars used were mixed with unwarmed water from the City mains, and with water warmed to 77° Fahrenheit. Tests were also made with Roman and Portland cements and cold water to which 7 per cent. of its weight of cooking salt had been added. All mortars were made with 1 part of cement and 2 parts of sand. In the mixed mortars twice as much lime as Portland cement was used.

The lower half of the walls was partly protected by timbers, but the upper portion was entirely exposed. A few tests were also made with brick masonry laid with Hansleitner's frost-proof Roman and Portland cements.

The test-blocks of rubble masonry were 1 meter long, 2 meters high and 16 inches thick. The stone used was partly limestone and partly sandstone. These blocks were made with lime mortar, Roman cement mortar and Portland cement

mortar, mixed with cold and hot water and cold brine, as before. The brick walls were started the last part of December, when the temperature was 26° Fahrenheit, and finished in about three weeks, the lowest temperature being 3° Fahrenheit. They were pulled down June 6.

It was at once apparent that the walls laid with mortar containing lime had suffered more from frost in the exposed upper portions than in those protected by timbering, since in the former the water had plainly been frozen. The joints were then examined with a sharp iron, wi h the following results:—

1. Lime mortar mixed with cold water—The mortar in the joints had hardened but feebly, and the bricks could be pulled apart by hand without exercising any noticeable amount of strength.

2. Lime mortar mixed with warm water—The mortar in the joints had hardened feebly, and there was no adhesion between the bricks and the mortar.

3. Roman cement mortar mixed with cold water—The mortar in the outer and inner joints had hardened moderately, and there was considerable adhesion between the bricks and the mortar.

4. Roman cement mortar mixed with warm water—The joints were quite brittle and the inner portions of the mortar not particularly well hardened; the adhesion between the bricks and mortar was quite good. The part of the wall protected by timbers was in better condition, and excelled any of the preceding walls.

5. Portland cement mixed with cold water—The joints were hard and the mortar clung well to the bricks. The protected part was better than the other in this case.

6. Portland cement mixed with warm water—The joints were hard, the mortar adhered well, and the entire piece of wall was a little better than any of the preceding.

7. Lime and Portland cement mortar mixed with cold water—The mortar was badly mixed, brittle and crumbling, but adhesive.

8. Lime and Portland cement mortar mixed with warm water—The mixture was uniform in this case, but the mortar

was brittle and not well hardened in the interior, although adhesive.

9. "Frost-proof" Roman cement mortar mixed with cold water—The mortar was well hardened and there was a good adhesion between it and the bricks. A plaster of the same material, put on a part of the wall, was thoroughly hard and without sign of injury.

10. "Frost-proof" Roman cement mortar mixed with warm water—This mortar was well hardened and adhered very well to the bricks. A plaster of the same material was thoroughly hard and without defects.

11. Wittkowitz Slag cement mortar mixed with cold water—The joints were brittle and the mortar fell into little particles when scratched out with the iron. The inner parts, which had hardened somewhat, were crumbling and showed but a slight adhesion to the bricks.

12. Wittkowitz Slag cement mortar mixed with warm water—The condition of this wall was but slightly better than of that last noted.

13. Roman cement mortar mixed with cold water, to which 7 per cent. of its weight of salt had been added—The mortar was brittle and crumbling, adhering but slightly to the bricks.

14. Portland cement mortar mixed with cold water, to which 7 per cent. of its weight of salt had been added—The mortar was well hardened throughout and adhered well to the bricks.

The masses of rubble masonry were started on December 28, and completed about two weeks later, the temperature ranging from 7° to 25° Fahrenheit. They were examined April 7, and found in the following condition:

A. Limestone rubble.

1. Lime mortar mixed with cold water—The mortar was completely frozen and brittle, and without any adhesion to the stones. The block had fallen completely.

2. Lime mortar mixed with warm water—The mortar was entirely frozen, brittle, and without adhesion.

3. Roman cement mortar with cold water. The mortar had hardened pretty well, but had not the slightest adhesion to the stones, which could be removed from their beds without injuring the latter.

4. Roman cement mortar with warm water. The mortar was quite well hardened, but did not adhere in the slightest degree to the stones.

5. Roman cement mortar mixed with cold water and salt. In this block there was a partial adhesion between the stone and cement, and the latter had hardened somewhat better.

6. Portland cement mortar with cold water. The mortar had hardened very well, and the adhesion between stones and mortar was quite good.

7. Portland cement mortar with warm water. The conditions were the same as with the last block, although the adhesion may have been a trifle greater.

8. Portland cement mortar mixed with cold water and salt. The mortar was very hard and adhered to the stones very well. The tearing down of the wall required considerable strength and necessitated the use of bars and other tools.

B. Sandstone Rubble.

1. Lime mortar with cold water. The mortar was entirely frozen brittle, easily broken, and without a trace of adhesion to the stones.

2. Lime mortar with warm water. The condition of this block was the same as that of the first.

3. Roman cement mortar with cold water. The joints were badly frozen, the mortar crumbling and slightly hardened. There was no regular adhesion between it and the stones.

4. Roman cement mortar with warm water. This block was in the same condition as the last.

5. Roman cement mortar mixed with cold water to which salt had been added. The mortar was well hardened and adhered fairly to the stone.

6. Portland cement mortar with cold water. The mortar was well hardened, but its adhesion to the stones was only partly good.

7. Portland cement mortar with warm water. The conditions were much the same as with the last block.

8. Portland cement mortar mixed with cold water to which salt had been added. The mortar had hardened very well and adhered firmly to the stones. The block could not be broken apart without tools.

The conclusions of the committee from these experiments are, that in brick masonry laid in frosty weather mortars into which any part of lime enters should not be used. Roman cement mortars behave fairly well under such conditions and Portland cement mortars give good results. The use of warm water gives somewhat better results and salt materially increased the resistance to frost. With rubble masonry, using either sandstone or limestone, lime mortar was entirely out of place, and Roman cement mortar gave poor results unless mixed with salt. Portland cement mortar behaved well, especially with the addition of salt.

The final recommendation of the committee is, that in laying brick or rubble masonry in winter, only Portland cement mortar should be used, mixed with salt, if possible.

Two young students of Thayer School of Engineering, Dartmouth College, Percy L. Barker and Henry A. Symonds, give in their graduating thesis an account of a series of experiments which they made to determine the effect of freezing on the strength of cement mortar. This thesis can be found in full in Engineering News, Vol. XXXIII, page 282, but the substance is given below.

The experiments were made upon prisms of mortar one inch square and five inches long. Six brands of cement were used, Newark, Hoffman, Alsen, Saylor's American Portland, Giant Portland, and Improved Union, which is a mixture of Portland cement and natural cement. The cement was mixed with sand in proportions of 1 to 1 and 1 to 2 and the mortar pressed into molds. When the prisms had become thoroughly set they were exposed in the open air until frozen, and after remaining in this condition for intervals of from 2 to 60 days were tested by cross-breaking. A few tests were made with prisms of neat Rosendale cement and a large number with

prisms in which salt had been mixed with the mortar in various proportions, mostly 1 part salt to 30 parts water.

The conclusions drawn by these young men, from over 7,000 tests, were as follows:

1. Portland cement mortar suffers no surface disintegration under any condition of freezing, but the strength is injured in a majority of cases, and sometimes as much as 40 per cent.

2. Rosendale cement is disintegrated upon the surface when exposed to frost while setting, the amount of injury depending to a certain extent upon the number of degrees of the exposure below the freezing point. Extremely low temperatures produce a greater effect upon the cement than temperatures near the freezing point.

3. The cohesion of Rosendale cement mortar may be entirely destroyed by immersion in water which becomes frozen around it.

4. In the case of Rosendale cement an increase of strength appears to be acquired under the conditions which it passes through while frozen.

This of course means the strength of that portion of the prism which is not disintegrated, and it is very questionable whether this conclusion is a correct one.

5. Salt used in the mixing water, in proportions varying around 1 salt to 15 water, assists the Rosendale cement to resist the disintegrating action to frost to the greatest advantage, but appears to have an injurious effect on the strength.

6. The Improved Union gives eminently satisfactory results. It shows the property of Portland cement as allowing no surface disintegration, and gives the characteristic of Rosendale cement in attaining an excess of strength under frost.

They also regard the following points as suggested by the results of their own and other experiments:

1. That Portland cement mortar is injured relatively less by freezing as the ratio of cement to sand decreases.

2. That Portland cement mortars are injured relatively less by the action of frost as the ratio of salt in the mixing water increases to as high as 1 to 15.

3. Lime, if of the proper quality, may be used with fairly

good results in brick masonry if kept constantly frozen for some time after laying, but is ruined by alternate freezing and thawing.

This conclusion is directly contradictory to that of the committee of the Austrian Society, and seems to have been based solely upon an examination of the mortar used in the masonry of paper mills at Olcutt Falls, Vermont. "Various mortars were employed on different parts of the works, as follows: Portland cement mixed with from 1 cement to 2 sand to 1 cement to 7 sand by volume. Rosendale was used with the same proportions of sand as the Portland. In the brick masonry an excellent quality of gray lime was used alone in the mortar and also mixed with Portland cement. The masonry was constructed in cold weather, a small amount being laid when the temperature ranged as low as 35 degrees below zero. The Portland cement mortar was in excellent condition. The Rosendale cement mortar had scaled to some extent, especially when exposed to the extremely low temperature before setting. At a few points the mortar was found to be softened into the body of the masonry, but was generally hard below the first half inch. The lime when mixed with Portland cement showed not the slightest injury from frost; when used alone in the mortar it appeared to act in a similar way to the Rosendale cement."

The writer is also indebted to this thesis for some other data which were not otherwise accessible to him.

Mr. George S. Morrison exposed a pail of water in which specimens of Rosendale and Portland cement were immersed to freezing. The water became solid to the bottom. Upon thawing the ice, the Rosendale specimens were found to have been reduced to sand, while the Portland specimens showed no injury. Hoffman Rosendale cement mortar was laid late in the fall around the waste way of the reservoir of the Hanover (N. H.) water works, and water stood around and upon it, more or less, during the winter. When examined in the spring, the upper layer was found to be little more than a mass of dust and scales. The same brand of cement laid in the masonry of the gate house of the same reservoir during cold weather

showed disintegration to about one-fourth inch depth, but seemed in good condition beneath.

In the report of the Royal Testing Laboratory of Berlin of 1886, an account is given of a number of experiments made to ascertain the effect of frost upon the strength of Portland cement neat and mortar made of 5 parts sand to 1 part cement. Two distinct series of briquettes were made, the first being exposed to freezing on and during the sixth day after mixing, while the second were treated as follows: (1) Allowed to set twenty-four hours in a warm room; (2) exposed twenty-four hours to freezing; (3) thawed four hours in a warm room; (4) immersed until tested. Upon testing the specimens it was found that the effect of freezing varied with the quality of the cement; the loss of strength by freezing ranged from 2 per cent. to 22 per cent. in the cement and from 3 per cent. to 24 per cent. in the mortar at seven days.

After 28 days a deterioration was shown of from 2 per cent. to 12 per cent. in the Neat cement and from 1 to 33 per cent. in the mortar.

The use of pulverized clay from a blast furnace gave a still greater loss of strength from freezing.

Mr. Wm. W. Maclay, C. E., in a paper in Transactions of the American Society of Civil Engineers, Vol. VI, gives the results of a series of experiments performed by him upon the effect of heating the ingredients of cement mortar and using the hot mortar at freezing temperatures. All the experiments were made with Burham cement. Two sets of briquettes were used. In one set the temperature of the cement paste averaged 40 degrees and the other 100 degrees Fahr. The sets were treated exactly alike and broken at the same time. The strength of the heated mixture was found to be only from 7 per cent. to 20 per cent. of that attained by the cold mixture. In the case of mortar made of 1 volume of cement to 2 of sand, the heated showed a strength of only 30 per cent. of that reached by the cold. Mr. Maclay concluded that the use of highly heated materials in mortar greatly reduces its normal strength. This conclusion differs very widely from the experience of many masons, and inasmuch as it does not appear to rest indisput-

able theoretical basis, and so far as known to the writer has not been confirmed by subsequent experiments, it should be accepted with hesitation if at all.

Mr. Alfred Noble, in Transactions of the American Society of Civil Engineers, Vol XVI, states "that in the construction of a lock at St. Mary's Falls Canal, the laying of masonry was discontinued about October 20 of each year, on account of the frequent recurrence of freezing weather. On the last day of work done in 1877 mortars of Portland cement and of a good quality of American natural cement were used in adjoining portions of the wall. The same proportions of cement and sand, 1 to 1, were used in both classes of mortar. This masonry was laid during a light rain. The following spring the surface of the Portland cement mortar was sound, showing perfectly the marks of the rain drops. The natural cement was disintegrated to a depth of 3 or 4 inches."

Mr. Noble also gives the results of some experiments upon Portland cement mortar with different proportions of salt in the mixing water. "Two series of experiments were performed, the first indicating no marked effect when the amount of salt was increased, while the second series showed a less effect from frost as the amount of salt was increased."

Mr. J. J. R. Cross, in Transactions of American Society of Civil Engineers, Vol. III, states that "mortar laid in the construction of a masonry dam in winter on the Croton River, where salt was used, gave perfectly satisfactory results. One pound of rock salt was dissolved in 18 gallons of water (about 1 to 150 by weight) at 32 degrees Fahr., and for each 3 degrees lower temperature three ounces of salt additional were used."

"Mr. J. F. Wallace used a brine of 8 per cent. salt in the mortar laid during cold weather in the construction of the Sibley bridge over the Mississippi River. The masonry showed no signs of injury from the low temperature to which it was exposed."

In "The Final Report on the Tennessee River Storage Project," by Geo. W. Rafter, C. E., to the State Engineer of New York, 1894, for which the writer is indebted to the courtesy of Albert J. Herries, C. E., Assist. Eng. N. Y. State Ca-

nals, the following passage occurs: "An experiment was made in a very rough way as to whether these concretes would stand winter weather when freshly made. For this purpose the surplus quantities of each mixing were made into a series of cubes of three feet, these cubes being built up in thin layers, well rounded, from day to day, as the tests went on. Block No. 1 was composed of Wayland cement for the first foot at the bottom, with the balance natural. No. 2 was about the same except that there was a layer of Portland cement concrete about one inch thick at the top. Block No. 3 was natural cement concrete, except a layer of Portland cement concrete six inches thick, about eight inches from the top. No. 4 was composed entirely of Portland concrete, except a layer of natural cement concrete about six inches thick and about six inches from the top."

Plate No. III in the report is from a photograph showing the appearance of these blocks March 17, 1894. Blocks No. 1 and 2 appear to have been reduced to shapeless masses. In block No. 3 the layer of Portland concrete appears thoroughly indurative and, so far as can be observed, entirely uninjured by frost.

In block No. 4 the Portland cement concrete is uninjured while the layer of natural cement near the top has crumbled the same as in the other blocks.

The boxing was allowed to stand around all these blocks until after the completion of the tests in December. They were therefore protected from the action of storms at the sides until after thorough setting had taken place.

The test by exposure to freezing indicates one point wherein the Portland cements, as a class, are superior to the natural, namely: they may be laid in moderately cold weather and, provided as small an amount of water as possible is used, no ill effect will be observed. The water is the destructive agent in freezing weather, and by reducing it to a minimum there will remain after chemical combination, little or none to disrupt. This practice, too, will be of advantage by adding to the strength of the mixture, as it is now well understood that an access of strength of the concrete follows a reduction of the

amount of water used in mixing; for the greatest strength the smallest possible quantity of water should be used. For very great strength the quantity of water may be so far reduced as to cause the mortar to resemble moist earth. When such mortar is added to broken stone which have first been well wetted and allowed to drain, the water may, by thorough ramming, be still flushed to the surface in a very thin film.

In freezing weather, therefore, the practice which prevents injury to the work will also be the proper practice for developing the greatest possible strength.

It has been a common practice to add salt to the water used in mixing in freezing weather in the proportion of about one per cent. of saturation for each degree below the freezing point. The weight of evidence is that for well proportioned Portland cement, this practice is entirely wrong—much better results will be obtained by the practice indicated in the foregoing.

Mr. S. D. Steele in a note to the American Society of Civil Engineers says: "Cement mortar is not seriously injured by being laid in frost, as its property of setting is simply held in suspension during the time it remains frozen."

Gen. Q. A. Gillmore, in his work on Coignet Beton, says "The effect of freezing on newly made beton is to detach a thin scale from the exposed surface," but "the injury does not extend into the mass of the material unless the frost be very intense." Also, "When the temperature ranges but slightly below the freezing point during the day, work may be safely carried on if care be taken to cover the new material at night. After it has once set and had a few hours to harden, neither severe frost nor alternate freezing and thawing has any effect upon it."

The following is an extract from a letter to the writer from Mr. Albert J. Herries in reply to an enquiry as to the practice on the new Lake Canals. "The subject is a highly interesting one and it is to be greatly regretted that while very large quantities of cement are used by us annually in freezing weather, we are still without any careful and scientific record of its behavior. However, while we cannot give you

any refined dates about the behavior of the cement, we have the most satisfactory of all tests, the test of many years of actual use, and I can say without any reservation that when the construction has been under the care of competent engineers, we have never had any difficulty or any bad results from cement mortar used in freezing weather. Our experience has been confined mainly to the use of natural cements and it has been our practice to use a saturated solution of salt in mixing the mortar, and to clean all stone thoroughly from dirt, snow and ice. We lay stone in as cold weather as men can work in, which in our damp climate is about 10 degrees F. The brine is tested with a salinometer; sometimes a potatoe has been used, but our proximity to the Nutmeg State has suggested to the minds of ingenious and economical contractors that wooden potatoes are more durable and are not injured by freezing. We therefore resorted to the salinometer.

"On lock 3 of the Cayuga and Seneca Canal in the spring of 1870, the masonry was completed so late that the mortar did not have time to set, and when water was let into the canal, the mortar washed out of the joints causing considerable trouble. We all think that salt retards the setting of the cement. No other experience of the kind has come to my notice."

It will be observed that the fact that natural cements are largely and successfully used on the New York canals seems to flatly contradict the conclusion of some experimenters that only Portland cement can be used with safety in freezing weather.

For the following three letters the writer is indebted to Mr. Dorr Skeels, a member of this committee.

The first is from G. S. Greene, jr., Engineer-in-Chief Department of Docks, New York City.

"In reply to yours of the 29th, ult., requesting some information in regard to the effect of cold and freezing weather on cement mortar and concrete, I beg leave to say in reply to your first question that much depends upon the use to which the mortar or concrete is to be put. If the concrete or mortar is to be subject to washing by water or if it is for any

reason desirable to have it set hard and quickly, the higher the temperature, that is natural temperature, the more satisfactory would be the result, because on the general principle that heat accelerates the chemical action, it would set quicker and harden in a short time. If, however, the concrete or mortar is simply to remain in air or in any position undisturbed, the slight acceration of the chemical action will not be of any particular advantage. In regard to your second question—'Is cement mortar made at 40 degrees Fahr. injured?' I think not, and in long experience have never known any to be injured at that temperature. In regard to whether the cement mortar is injured at 32 or 25 degrees, it is hardly practicable to mix mortar or concrete and set stones with the mortar or ram the concrete into position at 25 degrees Fahr. without heating the materials and possibly the tools with which it is handled. I have done work a number of times where the concrete was frozen, and the chemical action suspended by the cold, but where the concrete was not disturbed for 6 or 8 months, and found that the chemical action was simply suspended during the continuance of the cold weather, and as it became warmer the chemical action took place and the concrete set and became perfectly good work.

"My general instructions in making concrete in cold weather are, where it is not to be disturbed after being put in position, that it may be made as long as the materials do not freeze to the tools, or as long as the mortar does not freeze so that it cannot be worked with a trowel, or, in case of concrete, cannot be rammed."

The second letter is from Fr. von Emperger, C. E., from which the following extracts are taken:

"The German practice is not to work below 28 degrees F., mainly because working men quit work in colder weather. It is different in Norway where 12 degrees F. is taken as a limit.

"The only additional experience which I have is that even with 28 degrees in places where the wind blows or the sun has no access there may be a further depression, and it is also difficult to watch with a thermometer in the hand. I adopt the rule to always use salt if the water shows freezing, or the

stone. Nevertheless it is unavoidable that in stopping work the surface may get frozen before set if a sudden cold falls in, if not quickly and well covered, so that in starting again we cannot determine which part is frozen and which is not. We have then to pour hot water on the joint and scrape away all the loose material.

"Cold weather is always preferable for concrete work because it is generally damp, and I consider heat and drought more dangerous for fresh concrete than cold weather, because dry mortar concrete is absolutely valueless. It is further of advantage in work in connection with a water way to shut it off in winter while it is not in use. A further reason is that expanded walls may get cracked in winter while walls built in cold will expand without injury.

Mr. P. Amann, an Australian Engineer, has made some of his largest works during hard winters, and this time with trained men and proper precaution is generally commendable, but otherwise the general German code is good enough."

Mr. M. Murphy, Provincial Government Engineer, Halifax, N. S., furnishes the following items:

A paper read before the Institute of Civil Engineers, Great Britain, by A. E. Carey, on the inspection of Portland cement, in dealing with temperature, says:

The temperature of the water used for concrete making also deserves consideration. The experiments given in Appendix IV show the effect of freezing briquettes at various stages and for different lengths of time, and demonstrate that in cement, gauged as it is in making briquettes, frost produces no deleterious effect, the setting properties being rendered dormant thereby, and the long term tests being practically identical with those maintained at a higher temperature. In concrete making on public works, in which an excess of water is generally used, the effect of frost is to disintegrate the concrete by the expansion of the water in freezing, and measures to neutralize this effect have been investigated by the Russian and American authorities.

It has been found that the addition of common salt to the water enables work to be carried on during hard frosts, the

proportion of salt so employed even reaching 8 per cent. A temperature of 75 to 80 degrees Fahrenheit was found by experiment to hasten the maturing of the cement, a result to be noted in relation to work in tropical waters.

APPENDIX IV.

EFFECT OF FROST UPON CEMENT BRIQUETTES.

No. 1 Series.—Gauged in water of 55 to 60 degrees Fahrenheit, and immersed at a similar temperature, the tensile breaking strain was 540 pounds at seven days and 585 pounds at fourteen and twenty-eight days.

No. 2 Series.—Gauged as above, and exposed for forty-eight hours (setting being unusually slow) to temperatures ranging between 30 degrees Fahrenheit maximum to 22 degrees Fahrenheit minimum; then placed in water exposed in the open air. The temperature during the following five days ranged between 41 degrees Fahrenheit maximum and 22 degress Fahrenheit minimum, the briquettes being imbedded in ice. After seven days test, the temperature was slightly above freezing by day and 2 or 3 degrees below at night, but the ice did not thaw on the surface of the water. The tensile breaking strain amounted to 357 pounds per square inch at seven days, 552 pounds at fourteen days, and 395 pounds at twenty-eight days.

See Vol. CVII, Minutes of Proceedings of the Institution of Civil Engineers, pages 55 and 67.

MEMORANDA.

Mr. Carey's remarks may hold good when Portland cement concrete or Portland cement mortar is employed "en masse," such as in foundations and under water where the temperature may be uniform, and where the crystalization can be homogeneous throughout the entire body. When employed in work above the surface, such as in piers or walls having an exposed and varying in temperature, the results may be different.

Immediately after the concrete material is deposited in a plastic condition, it undergoes quite a change to a higher temperature, while, on the outer or exposed surface with a lower

degree, the same conditions cannot exist; and though the different thermal conditions of change, within and without, may be small, we cannot doubt that the total effect produced by these changes is considerable. Hence, as in small crystalline bodies, cooling and setting under similar conditions, cracks will invariably occur.

If the work has been carried on in a temperature of 45 degrees Fahrenheit the changes through the mass will be so small that there cannot be any deleterious effects. If we have a temperature of zero outside, whilst within the body it is very much higher, the setting or crystallization which takes place in the cooling, cannot be uniform or homogeneous, and different results must be expected.

The intermediate temperatures, such as that of 25 degrees Fahrenheit must also, more or less, affect cement mortar or concrete. In Nova Scotia, the changes of temperature may vary from 10 to 15 degrees Fahrenheit in a few hours. When working late in the season I have been caught by these sudden changes and my experience has been such that, when the temperature approaches the freezing point of 32 degrees Fahrenheit, I immediately stop the work. I have built ashlar masonry in Portland cement mortar when the thermometer stood at 10 degrees Fahrenheit, and sometimes lower, and found the work in fair order the following spring. I could not, however, recommend that concrete work above the surface be performed in a temperature of less than 32 degrees Fahrenheit, even then the face of the work is liable to disintegration.

During the summer season, when it is above 75 degrees Fahrenheit, the same deleterious effects will take place, and the same remarks may be applied in an ascending scale. In hot weather exposed concrete should be kept covered and frequently damped with a sprinkling of water to ensure smooth and solid face work.

In cements other than Portland, such as natural cements, where the quantity of free lime is greater, the deleterious effects must be proportionally greater. Where cement mortar is used in masonry in very cold or freezing weather, the ex-

posed points ought to be raked out and pointed when the season is more favorable.

The Engineering Record, Vol. XXIX., page 59, in an editorial reply to a correspondent, says: "If Rosendale cement must be used in freezing weather it would be better to use salt water (perhaps 1 or 2 per cent. solution). Many good cements are not sensibly affected, although even a little salt probably slightly impairs the strength at advanced age. The initial effect of the salt is an acceleration of the hardening of the cement.

Mr. Charles Robert, Engineer of the Western Railway of France, gives in "Le Genie Civil" his experience in handling mortar for masonry in freezing weather. His company had tried mixing alcohol and marine salt with water, and finally adopted the ordinary soda of commerce. This latter gave the best results in reducing the liability of the mortar to freeze; and in the winter of 1891–2 a considerable amount of masonry of all kinds was laid on the line, even in a temperature of 5 to 14 degress F. above zero. Among the works executed was an arch of 50 feet span, with the masonry laid up in lime mortar without cement. From his experience the following rules for mixing the soda with the mortar have been adopted. He used the hydrous carbonate obtained by the Solway process, as it costs less for transportation and hand labor than the hydrated carbonate. This soda comes powdered in sacks. It is dissolved in a kettle in which is constantly maintained a desage of 1 kilogram (2.2 pounds) to 5 litres (5¼ quarts) at a temperature of 86 degrees F. This solution is mixed with an equal volume of ordinary water in the tubs from which the masons obtain the water for the mortar. This is used at a temperature of 50 to 53 degrees F. In preparing the mortar the proportion of water usually employed in a mortar of 1 part sand to 1 part lime should be increased about one quarter. Sand frozen on the surface should be carefully pulverized and it is well to provide the workmen with rubber gloves. The increased cost due to the admixture of soda, with the soda at 4 cents per kilometer and at 7 cents per hour for hand labor, is about 37 cents per cubic yard of masonry.

Mr. Robert says that the addition of the soda not only makes it possible to mix the mortar and to preserve it in a low temperature, but it also hastens the setting. With the proportions above given, the soda mortar exposed to a temperature of 23 degrees F. has set twice as promptly as the same mortar without the soda at a temperature of 14 degrees F. At the surface for a depth of .16 to .20 inch, the hardening is much quicker. The interior during the setting process remains humid. This has been proven by pulling down masonry after five months, and when exposed to the air the mortar dried rapidly.

These results have been obtained with masonry exposed to the air. With the mortar immersed in water strongly impregnated with soda, the set has been much accelerated. The use of soda causes white blotches to appear on the surface of the masonry; but these disappear after some months. This fact and the persistent humidity of the interior, practically forbids its use in the fronts of buildings, but it may be used in all other works.—[Eng. News, Vol. XXIX, page 146.—Eng. Record, Vol. XXVIII, page 348.

Mr. Bernhofer, an Austrian Engineer, has had a similar experience with soda. In December, 1890, he used a mortar consisting of 1 litre of Portland cement, 1 litre of lime and 3 litres of river sand mixed with a solution of 1 kilogramme of crystalized soda in 2 litres of water. This mortar was exposed to a cold of maximum intensity of 31½ degrees below zero (Cent.) for 14½ hours, and was then put into a hot furnace for 3 hours. At the end of that time the set of the cement was found to be perfect.—[Eng. News, Vol. XXIV, p. 316—Vol. 26, p. 203.

These experiments would seem to show that an admixture of soda is an effectual preventative of the injurious effects of frost, but its much greater cost would seem to forbid its use instead of salt if salt will answer the purpose.

There appears to be quite a general opinion among engineers that the strength of cement mortars and concretes is considerably lessened by mixing with and immersing in salt water. Gen. Gillmore, in his work on "Limes, Hydraulic

Cements and Mortars," page 166, expresses this opinion founded upon some experiments of his own, and this opinion has been generally accepted.

Mr. F. Collingwood, in a paper before the American Society of Civil Engineers, November, 1895, states that a certain cement which gave excellent results when mixed with fresh water was inferior to others when salt water was used.

More recent experiments by Mr. Elliot C. Clarke, in connection with tests of cement for the Boston Main Drainage Works (Tran. Am. Soc. C. E., Vol. XIV, p. 155) with both Rosendale and Portland cement mortars mixed with both fresh and salt water and immersed in both fresh and salt water, seemed to indicate "that salt either in the water used for mixing or that of immersion has no important effect on the strength of cement, except to slightly retard the first setting."

Still more recent tests by Mr. John Gartland from May, 1889, to July, 1890, on 15 different brands of cement and 2,531 briquettes, "showed in every instance but one (Hoffman Rosendale, 2 months) that cement used with salt water is much the stronger. The favorable effect of the salt seemed more marked on Rosendale than on Portland cements. The permanent gain in the strength on the former seemed to be about 20 per cent., more or less, while on Portland cement at least 10 per cent. gain was indicated."—[Eng. News, Vol. 24, p. 542.

Mr. M. J. Powers, in some laboratory experiments extending over 13 weeks on 3,500 briquettes of both Portland and natural cements, arrived at the conclusion that cement mixed with salt water gains considerably in strength during the first few weeks, but that the gain is not permanent; that the gain is greater and more permanent with the Portland than with the natural cements, and that the effect of using a 10 per cent. solution seems not as good as with a 3 per cent.—[Eng. News, Vol. XXVI, page 481.

Mr. Walter Katte's General Specifications for Railroad Construction contains the following provision: "Masonry may be laid in freezing weather by using salt water for mixing the mortar. Dissolve one pound of rock salt in eighteen gal-

lons of water when the temperature is at 32 degrees F. and add one ounce of salt for every degree lower of temperature, or enough salt, whatever the temperature may be, to prevent the mortar from freezing. No masonry laid in freezing weather to be pointed out until spring." Precisely similar specifications have been used at Scranton, Pa., and other cities.

The Specifications of the Metropolitan Sewerage System of Boston, 1890, provides: "When work is done during freezing weather the contractor shall provide the necessary means for, and shall heat the bricks, gravel, sand and water, and shall comply with all the requirements of the engineer to thoroughly protect the masonry from damage from frost during and after laying. No work shall be done on masonry during such days as, in the opinion of the engineer, good work cannot be done,—all unfinished shall be properly protected during inclement weather from injury from water or frost."

Similar provisions may be found in other specifications where reliance seems to be placed entirely upon heating the materials.

Prof. Baker in his "Treatise on Masonry Construction," says: "It does not appear that common lime mortar is seriously injured by freezing, provided it remains frozen until it has fully set. The freezing retards but does not entirely suspend the setting. Alternate freezing and thawing materially damages the strength and adhesion of lime mortar. Although the strength of the mortar is not decreased by freezing, it is not always permissible to lay masonry during freezing weather; for example, if, in a thin wall the mortar freezes before setting and afterward thaws on one side only the wall may settle injuriously. Mortar composed of 1 part Portland cement and 3 parts of sand is entirely uninjured by freezing and thawing. Mortar made of cements of the Rosendale type, in any proportion, is entirely ruined by freezing and thawing. It is probable that this difference is due to the fact that the expansive force of water in freezing is less than the strength of the richer Portland cement mortars and greater than any Rosendale cement mortar. In the latter case freezing is equivalent to agitating the mortar after it has partially set. Mortar

made of over-clayed cement (which condition is indicated by its quicker setting) of either the Portland or Rosendale type, will not withstand the action of frost as well as one containing less clay; for since the clay absorbs an excess of water, it gives an increased effect to the action of frost. Thus far we have confined ourselves mostly to the conclusions of engineers and scholars derived from experiments on a comparatively small scale and largely, perhaps, under conditions different from those which occur in actual practice. We now add some data from the experience of practical masons and contractors.

Mr. Wm. H. Ward, a contractor who had occasion to put in many thousand cubic yards of Portland cement concrete for street railways in Brooklyn, much of which was done in the winter, thus describes the material which he employed in cold weather: "A large water-tight tank, open at the top, was constructed, of such dimensions as would allow three ordinary dirt boxes to be lowered into it at the same time. This tank was filled with water and a jet of steam kept the water hot in the coldest weather. The broken stone or cobbles, designed for the concrete, were loaded into these boxes and lowered into the tank of hot water. A bath of a few minutes duration heats the stones to the temperature of the water. One of the boxes is then hoisted out and dumped on one side of the mixing machine, the stone with sand and water in proper proportions is run through the machine and wheeled to the place of deposit without delay. In this way with layers ten or twelve inches deep, well warmed, the heat is retained until the cement becomes firmly set and makes an almost impenetrable mass. In severely cold weather additional protection is secured by heating the sand and water before using. When the temperature is low it is well to protect the work by a cover of hay, gunny cloth, or other convenient material."—Engineering News, Vol. XXXI, Page 181.

The following letter to the writer gives the valuable experience of a mason who has had an unusually large practice in winter work, some of it in the extreme climate of Northern Michigan:

MANISTEE, Mich., Dec. 3, 1895.

I have been requested to give my experience in the use of cements and quick lime mortar in winter or freezing weather, and will try to do so as a practical mason. My first experience was in the winter of 1853–54, at Jonesville, Mich., working with my father, who had the contract to build the brick chimney, 64 feet in height, and set the engine and boilers for the woolen mills at that place. We used the Ohio lime and Akron cement. We slaked our lime dry in sand in cold, freezing weather, and after mixing it with the sand sifted and mixed it for use as we needed it. This kept it from being frozen before using, and we used care in selecting dry brick, so the moisture would be absorbed from the mortar as quickly as possible when laid in the wall, and then the frost would not swell and burst the joints, and destroy the beauty and strength of the wall, which would be the case if the brick were wet or frosty and the mortar cold, as then the frost would form ice in the joints of mortar and swell and destroy them, as I said before, instead of helping to absorb the moisture and set the points, as it would if the brick were dry and the mortar warm. I have found in all cases where such care has been taken that walls laid in the very coldest weather are stronger than they would be if laid in the heat of summer, for the reason that the mortar dried slower and adhered firmer to the brick. And in using cements of every kind I have found the same care necessary as regards drying of frost out of the stone or brick used, so that there would not be sufficient moisture left to form ice and swell the mortar. Wherever these precautions have been taken the work has always been good, and I write this after forty years' experience, north and south, on house, store and mill work. I can refer to plenty of such work done in the coldest of our Michigan weather which is standing today and is the best proof of what I have here written. I will mention a few of them that I have had personal supervision over: Dempsey and Manistee Lumber Company, boiler house; Eureka Salt and Lumber Company, boiler house and engine foundation; the boiler house and engine foundations and furnaces of the Buckley & Douglass Lumber Company, the Jacob Aarons stores, First Congrega-

tional Church, and the furnaces of the Canfield & Whalen Company, all of Manistee, Mich; my old home in Jonesville, Hillsdale County, the Government Rolling Mill at Chattanooga, Tenn., furnace and stack built under direction of William Bettilar, U. S. Engineer, in 1864–65, and many others which I could call your attention to, that are in good condition to-day that were built from 1853 to within the last few years, on which I have worked or have had charge of.

WM. T. BRAIN,
Brick and Stone Mason and Contractor,
380 First St., Manistee, Mich.

Mr. Brain's experience includes the use of common lime, Portland and natural cement, and much of his work was done under very unfavorable circumstances, that at Chattanooga when it was freezing and thawing every day, and some of that at Mainstee in the very coldest weather when, the work would freeze as fast as it was laid, and a mason could not work without overcoat, mittens and ear-tips, and a large part of a bucket of mortar would freeze hard while the rest was being used. It will be observed that his success has been based upon the use of as dry materials as possible, and he also recommends using hot sand and water and heating the stone enough to take out the frost.

The reader, on looking over the mass of material which we have here presented, will readily observe that there is a wide difference of opinion among engineers and practical men on several points.

One claims that common lime mortar is worthless in freezing weather, another has used it with perfect success; one claims that natural cement mortar is destroyed by frost, another points to its successful use for many years. Some say that the use of salt diminishes the strength of mortar, others that it increases it; some that salt retards the setting, others that it hastens it. One uses an extra dose of water in freezing weather, another uses the least possible quantity. Some recommend heating the materials, while others claim that heat injures the mortar. At first sight one almost feels like exclaiming with the showman, "You pays your money and you

takes your choice." It is plain that the subject has not been reduced to an exact science and that there is still wide room for careful experiment. It would seem, however, that from the mass of facts it is possible to deduce some principles.

The setting of mortar is largely a chemical process requiring as an essential element a certain amount of water in a liquid form. Frost by changing this water into the solid form of ice destroys its power of chemical combination in the same manner as if it had changed it into particles of sand, and the process of setting is stopped. It has the additional effect of causing the disintegration of the mortar by the expansive force of the water in freezing, unless it has acquired sufficient internal strength to resist this force. This effect is evidently less as the amount of moisture in the mortar is diminished. It would seem then that any process would be useful which, without injuring the quality of the cement, would retard the freezing until the process of setting is completed or is sufficiently advanced to resist the action of the frost. This would be a sufficient explanation of the useful effect of salt, soda, heat, protection and the removal of surplus moisture. Assuming that these conclusions are correct the writer ventures to suggest the following rules to be observed in part or in full when it is necessary to construct masonry in freezing weather.

1. Use Portland cement in preference, if practicable, if not, those brands of Rosendale cement or common lime which have shown the best behavior.

2. Mix the mortar or concrete in a spot sheltered as much as possible from cold winds.

3. Use the least amount of water that will be sufficient to enable the mortar to set.

4. Heat the water and sand for the mortar and the broken stone or gravel for concrete. Warm the brick or stone for masonry sufficiently to remove the frost, but not enough to make it difficult to handle.

5. Mix salt with the water in the proportion of 1 pound to 18 gallons of water at 32 degrees F. and one ounce additional for each degree below 32 degrees.

6. Use the mortar or concrete as quickly as possible after it is mixed, before the heat is dissipated.

7. Protect the unfinished masonry as much as possible from cold winds and cover it at night or when work is suspended.

8. Leave the pointing of the masonry until warm weather.

B. F. La Rue.—In a recent conversation with Mr. Geo. Leighton, who was assistant engineer on the masonry work of Washington Bridge under Mr. Alfred Noble, Resident Engineer, Mr. Leighton made the following statement concerning work done in freezing weather:

"This work was in progress during the winter of 1887–88. Portland cement was used for laying the arch stones, in face walls and below water line, while Rosendale cement was used in backing and interior walls. A considerable amount of both was laid in freezing weather, a certain quantity of salt being sprinkled upon all mortar mixed in such weather. Instructions were that no masonry should be laid with more than 20 degrees of frost (below 12 degrees above zero). I made frequent and careful examination of the work laid in freezing weather and took notes of its condition.

"In masonry laid in freezing weather with Rosendale cement, when examined in a frozen condition the mortar was found to show decided efflorescence, the salts of the cement upon its surface having the appearance of hoar frost. At such examinations it was my opinion that the mortar would be much injured. But when again examined in the spring, after the frost had disappeared, the essential portions of the mortar joints were found to be in excellent condition. No difference could be discerned between this mortar and that laid in warmer weather, except that in the mortar laid in freezing weather the surface of the joints had crumbled away to a depth of about a quarter of an inch, exposing a perfectly hard and firm mortar beneath,

"The Portland cement mortar was found to be in all respects perfect and apparently unaffected by the frost."

Mr. W. H. Sadler, Assistant City Engineer of Scranton. Pa., a gentleman of extensive experience in masonry construc-

tion, gives the following opinions as the result of his observation and experience:

"In using mortar in freezing weather, I would protect the mortar box from the wind and would sprinkle just enough dairy salt upon the mortar to prevent freezing. I would also heat the sand and heat the water, putting some salt in the water. A small proportion of water should be used and the mixing should be very thorough as well as rapid. Too much water is used in very many cases. Dairy salt is better than rock salt. Only sufficient salt to keep the mortar from freezing should be used. Too much salt makes the mortar slippery and discolors the work. The freezing of mortar is most troublesome in the morning.

"In my opinion the effect of frost upon Portland cement mortar is not directly injurious, except that it retards the setting. The damage to the work is that the freezing of the mortar prevents the workmen from properly bedding the stones. Heavy work can be constructed in freezing weather more advantageously than light work. It would be inadvisable to attempt to lay thin walls or work having close joints in freezing weather, or to do any pointing. Hydraulic work laid in freezing weather would be very apt to leak. I would not attempt to use natural cement in freezing weather. When the temperature falls below 10 degrees above zero, I would suspend all masonry work unless very urgent."

M. J. Becker, C. E., Past President of the American Society of Civil Engineers, says, "As a mere matter of precaution I have, in my own practice, always made it a rule not to build any masonry in cold weather; in a few instances, where I could not adhere to this rule and had to build some brick arches in tunnels, I took my chances, presuming somewhat upon the sheltered location, and continued work during cold weather, and I found that the mortar used in pointing the joints, which was Louisville cement and contained but very little sand mixture, scaled off in the succeeding spring and had to be repointed. Perhaps pure Portland would have given better results."

(COMMENTS ON PAPERS IN THE ENGINEER'S ANNUAL FOR 1895.)

CEMENT AND CONCRETE.

A More Simple System of Testing Cement.

B. F. LA RUE.

In discussing Mr. Hillyer's valuable paper on the above subject, read at the last annual meeting, Col. Muenscher stated that "What the average engineer wants is a more simple system of testing," and in this connection referred to the graduating thesis of two engineering students, having for a subject the testing of cements.

These young men, Herman E. Abbott and Edwin J. Morrison, made a large number of tests of various cements, 1,438 in all, for the purpose of determining their strengths, both in direct tension and in flexure. (See Engineering News of Dec. 14, 1893, and May 10, 1894). I believe the latter method of testing cement to be worthy of further attention and venture to offer the following observations along the line suggested by Col. Muenscher and as supplementary to his remarks.

Testing by transverse or cross breaking stress would seem to be the most rational as well as the most simple method of determining the practical value of cement. The principal disadvantage of this method of testing is that the strength of the cement, as computed from transverse tests by applying the common theory of flexure, will not be the same as when obtained by testing the same cement in direct tension. Cement is weaker in tension than in compression, and, when broken by flexural stress, rupture will occur on the tension side of the beam. It would, therefore, seem as though the tensile strength of this material should be indicated by flexure tests. But the strength of cement, as computed by applying the common theory of flexure to cross-breaking tests, is, roughly speaking, found to be nearly one and three-quarters times the strength

of the same cement broken in direct tension. This was shown by the tests of Messrs. Abbott and Morrison referred to, in more than 500 of which tests very just comparisons between the two methods of testing were afforded.

The explanation commonly given for this somewhat phenominal disparity in the results obtained by these two methods of testing, is that the common theory of flexure does not apply after the elastic limit of the material has been exceeded. This difficulty, if insurmountable, would prove a severe obstacle to the testing of cement by transverse stress. I do not wish to here attempt any theoretical discussion of this subject, but simply to call attention to a simple formula by the use of which this disparity of results may be practically reconciled, so far as the testing of cements be concerned.

According to the common theory of flexure, the moment of resistance of any beam is given by the formula, $R=\frac{SI}{c}$ in which R is the moment of resistance, I is the moment of inertia of the cross section, c is the distance of the most remote fiber from the neutral axis, and S is the unit stress in this remote fibre. As stated above, when applied to flexure tests of cement this formula will give values for the unit stress much in excess of the strength of the same cement tested in direct tension, and the same is quite generally the case when applied to transverse tests of other materials.

Now, I have noticed that by substituting the radius of gyration, r, for the distance, c, in the formula $\frac{SI}{c}$, thus giving it the form $\frac{SI}{r}$, the results obtained by applying the formula to transverse tests of such inelastic materials as cast iron and cement will agree very closely with the strengths of the same materials as obtained from tension tests. By comparing on this basis, 896 flexure tests of cement, made by Messrs. Abbott and Morrison, with 542 tension tests, made by them on the same cements and under as nearly as possible the same conditions, the average difference between the results obtained by the two methods of testing was only 6 per cent.

which, for a material as variable as cement, is as close as could be expected. These tests had been made with especial reference to obtaining a comparison between the two methods of testing and, consequently, the comparison is fair and reliable.

Therefore, without reference to the theoretical features of this formula (I am aware that it is not supported by accepted theory), I believe that I am justified in recommending it as a reliable formula by which to compute the breaking stress in flexure tests of cement. The only claim which I here make for the formula is that it will, in all cases and for all forms of cross section, give practically the same results as tension tests of the same material. As this claim appears to fulfill all requirements for a formula for computing the results of flexure tests, I will put it in a form convenient for practical use.

For a beam of rectangular cross section, the expression $\frac{S\,I}{r}=\frac{S\,b\,d^2}{3.464}$, in which b is the breadth and d is the depth of the beam. If it be a simple beam of span, L, loaded midway between its supports with a single load, W, we will have $\frac{W\,l}{4}=\frac{S\,b\,d^2}{3.464}$, from which $S=\frac{.866W\,l}{b\,d^2}$. If the beam is a rectangular prism of a cross section one inch square and S be taken to represent the ultimate strength per square inch, we will have S=.866Wl or, for convenience in remembering, we may say that the stress per square inch is equal to the product of the center load W, the span, l, and the sine of 60 degrees.

I give below the value of S in terms of W for prisms one inch square on various spans of convenient length. In each case, S is the ultimate strength per square inch and W is the load applied midway between supports.

For l=2 inches, S=1.732W (W×1⅓).
" l=3 " S=2.598W (2.6W).
" l=3½ " S=3.031W (3.03W).
" l=4½ " S=3.897W (3.9W).
" l=5 " S=4.33W (4⅓W).
" l=6 " S=5.196W (5.2W).
" l=7 " S=6.062W (6.06W).

The values in parentheses are near enough for practical purposes.

I would recommend as a standard that the prisms of cement be made one inch square and seven inches long; that the original prisms be first broken on a span of 5 inches and the shorter pieces thus obtained be broken upon a span of 3 inches. The prisms should be exactly one inch square, the length of the span should be accurate and the load should be applied exactly at the center of the span.

One advantage of the method of transverse testing over that by direct tension is the greater percentage of good breaks that can be obtained. In testing cement by direct tension, as is well known, it is difficult to so adjust the clamps as to obtain a direct and uniform pull, producing a good break. Another advantage of the transverse method is that, after having broken a prism of cement on the adopted span, one of the pieces and often both of them can be again broken upon a shorter span. To quote Mr. Morrison's language, "This would be an enormous advantage for the transverse method of testing, since from each prism we would get two, and often three, good tests instead of one doubtful one from each briquette broken by tension."

The apparatus required for transverse testing is simple. That used by Messrs. Abbott and Morrison was described in Engineering News of December 14, 1893.

In recommending this formula for transverse testing, I had intended to leave the value of S either to individual judgment or to the consensus of opinion as developed in the discussion which I trust these observations will lead to. But it has been suggested to me that my discussion and recommendations will be of greater value if I propose a minimum value of S for a good and reliable cement. I will, therefore, propose such values as seem to me to be reasonable and consistent, trusting that they will be critically discussed, and modified if thought advisable.

Cement is not a uniform material. Its strength, when tested, is found to vary greatly and will but roughly approximate any adopted standard. Portland cement is considerably

stronger than natural cement. Any cement is stronger when mixed neat than when mixed with sand. Cement which would be satisfactory for certain work might not prove satisfactory for work of a different nature. Moreover, it should always be remembered that the quality of the sand used, and the thoroughness and rapidity of manipulation, have about as much to do with the strength of the resulting mortar or concrete as has the quality of the cement.

I prefer American Portland cement; and for a good quality of work under ordinary conditions, have specified about as follows:

"The cement used will be, preferably, the best American Portland, well burned, heavy, and so finely ground that not more than 20 per cent. will be retained on a sieve having 10,000 meshes to the square inch (No. 100); when mixed neat, it shall show a minimum tensile strength of 100 pounds per square inch at the end of 24 hours and 300 pounds per square inch at the end of 7 days."

These requirements are at about the minimum tensile strength of neat Portland cement and are easily complied with.

In the report of a committee of the American Society of Civil Engineers, appointed to devise a uniform system for tests of hydraulic cement, read in January, 1885, the following were given as "The average minimum and maximum strength per square inch which some good cements have attained." Figures in parentheses are mine:

		American and Foreign Portland Cement.				American Natural Cement.			
		Neat.		1 part Cement 3 parts Sand.		Neat.		1 part Cement 1 part Sand.	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
1 Day	1 hour, or until set, in air, the rest of 24 hours in water	100 (110)	140			40 (50)	80		
1 Week	1 day in air, 6 days in water	250 (325)	550	80 (91¼)	125	60 (70)	100	30 (35)	50
28 Days	1 day in air, 27 days in water	350 (437½)	700	100 (125)	200	100 (112½)	150	50 (57½)	80
1 Year	1 day in air, The remainder in water	450 (537½)	800	200 (237½)	350	300 (325)	400	200 (225)	300

As the quality of the cements produced has somewhat improved during the ten years which have elapsed since this report was made, I think it will be not unreasonable to adopt, for a standard minimum strength in tests, values at one-fourth the range between minimum and maximum, above the minimum values given in this report. Such values of the tensile strength are written above in paretheses. Assuming these values for S and neglecting fractions in the results, the following values are obtained for the minimum center breaking weight, W:

TIME OF TEST.	PORTLAND CEMENT.				NATURAL CEMENT.					
	Neat.		1 part cement, 3 parts sand.		Neat.		1 part cement, 1 part sand.		1 part cement, 2 parts sand.	
	5 inch span pounds.	3 inch span pounds.	5 inch span pounds.	3 inch span pounds.	5 inch span pounds.	3 inch span pounds.	5 inch span pounds.	3 inch span pounds.	5 inch span pounds.	3 inch span pounds.
24 hour test	25	42			12	19				
7 day test	75	125	21	35	16	27	8	13	5	8
4 weeks test	101	168	29	48	26	43	13	22	8	13
1 year test	124	207	55	91	75	125	52	87	31	52

It will be noticed that I have added the values of W for 1 part natural cement to 2 parts sand, these being the proportions commonly used for this cement. From such data as are available, I infer that the strength of natural cement mortar mixed 1 part cement to 2 parts sand is about 60 per cent. of that of mortar mixed 1 part of the same cement to 1 part sand.

In selecting cement for masonry, the 24-hour test and the 7-day test are the only preliminary tests ordinarily available, although the 4-weeks test can usually be made during the progress of work.

While the above values proposed for the minimum per-permissible breaking weights in transverse tests, seem to be consistent and will probably serve as a reasonably reliable discriminating basis for indicating the quality of cements, it must be remembered that but comparatively little is known concerning this method of testing cement, and it is quite possible that these values may prove unsatisfactory. I would

recommend that a committee be appointed to investigate the subject and make a series of tests, reporting at the next annual meeting.

C. E. Greene.—I am not persuaded by the argument of Mr. La Rue, and see no propriety in introducing the symbol, *r*, as he does. Mr. L. C. Sabin, Assistant Engineer at U. S. Engr. Office, Sault Ste. Marie, has had wide experience in testing cement, and might speak with authority on this matter, as well as effect of freezing.

HIGHWAY BRIDGES IN THE MANUFACTURER'S HANDS.

DISCUSSION BY BENJ. F. LA RUE.

In Mr. Vedder's paper on the above subject, after mentioning the incompleteness of plans forming part of the usual contract for a highway bridge, especially with regard to matters of detail, he makes the statement that "To insure satisfaction in details, complete working drawings should form part of every contract, which should conform to safe standards and the finished bridge should always be subjected to tests with observations for deflection." This statement involves matters upon which there may exist some honest difference of opinion; they are of sufficient importance to be worthy of discussion.

For complete working drawings to be made a part of the contract, I do not think to be always either necessary or expedient. It is quite generally the practice for those submitting proposals for highway bridges to bid upon their own designs, the general features of which are shown upon what are commonly known as strain sheets. It would be neither just nor sensible to require all bidders to submit complete working drawing with their proposals. Nor would it be expedient, after receiving the bids, to delay making the contract until the favored bidder could make complete working drawings. Furthermore, I believe that it is safe to state that the average official who is intrusted with the purchasing of highway bridges would understand no more, if not actually less, from the working drawings than from such drawings as are commonly exhibited. I thoroughly recognize the vital importance of efficient constructive details, and I am also aware that the details of highway bridges are frequently slighted and are very commonly not what they should be. But I do not think that satisfactory details would be insured by including the working

drawings in the contract, though, possibly, such practice might tend to some improvement in the details. As noticed above, this practice, if rigidly followed, would involve some inconvenience.

But the contract should, at least, always stipulate that complete working drawings shall be submitted for approval and be approved, before actual work is commenced. These drawings should be submitted to an expert by the officials having the matter in charge; they should also be preserved as a record of the structure. In case of any failure of the structure or litigation concerning it, such drawings would be of value.

In this connection I cannot do better, perhaps, than to quote the words of Mr. Edwin Thacher in a written discussion appertaining to Mr. J. A. L. Waddell's General Specifications for Highway Bridges. Mr. Thacher's language is directly to the point, as follows:

"I would prefer to have general directions sufficient to insure a first class bridge and leave most of the details to the designer. * * * A simple strain sheet and specifications would be as satisfactory to an expert as anything further, and if not submitted to an expert, it matters little how much is shown. It should be sufficient if full detail drawings are submitted for approval before work is commenced. * * *

"Almost any of the specifications used by the bridge companies are safe enough, and those are the best which give the greatest strength for the least money. The trouble is not so much in the specifications as in seeing that they are faithfully carried out. This can be accomplished at a small expense by employing an expert of known ability to examine plans and strain sheets, and a competent inspector to examine sections, material and workmanship."

In cases where a consulting engineer is employed to make a complete design for the structure, with detail drawings, the complete drawings should form a part of the contract. And this is, without doubt, the best method of letting the contract for a bridge.

But where bidders are allowed to bid upon their own designs, (and this practice possesses certain advantages), I think the requirement that complete detail drawings shall be submitted and approved before work is commenced is a practicable requirement and productive of good results. This requirement, however, amounts to nothing, practically, unless the drawings are submitted to an expert. But this is, of course, simply another method of including the complete detail drawings in the contract, and perhaps Mr. Vedder intended that such liberal construction should be given to his statement.

I do not agree with the statement that, "The finished bridge should always be subjected to tests with observations for deflection." Such so-called tests are generally little more than farces, and, even when carried out in good faith, with careful observations for deflection, I doubt if the information thus obtained is of any real value.

In reference to this subject quite a controversy appeared in some of the German technical papers in 1892, the Centralblatt der Bauverwaltung taking the initiative. This journal held that "While unduly great deflection of a structure under a test load unquestionably demonstrates weakness, moderate deflection is no guarantee whatever of safety." In all material points this view is correct.

The deflection test will, to some extent, indicate the safety of the structure. It may be an evidence of the strength of the main members. It does not, however, to any appreciable extent, indicate the strength of the details; and the details are the parts to which the most critical inspection should be directed. For, when failure occurs in a bridge, it is usually in a detail. It may also be remarked that the calculations for theoretical deflection, depending upon a quite variable coefficient of elasticity, are not very reliable indications of what should be the actual deflection of a structure. For these reasons, it is my opinion that observations for deflection give very little valuable information concerning the actual strength of a structure.

But it may be pertinently remarked that it is easier to say that a thing is not good than to propose a satisfactory substi-

tute. And this applies with especial pertinence to the ordinary methods of letting the contracts for highway bridges. For, unsatisfactory as these methods are, it is difficult to suggest a more satisfactory substitute. It is extremely difficult to devise a plan by which the interests of a purchaser, who knows practically nothing about the article which he is buying, are to be protected in a contract. This is especially the case when the seller is exceedingly well posted in regard to the article. I confess that about the only way I know for such a purchaser to be protected, is for him to employ some one, who does understand the matter, to advise him.

But there appears to be a decided disinclination, on the part of the officials who purchase highway bridges, to employ a consulting engineer to advise them. This may be because they fail to appreciate the benefits to be derived from so doing, or, perhaps, it is because they think that it would be equivalent to tacitly admitting that they do not understand their business. Whatever the reason, the fact remains. An official once said to me that he wanted to be re-elected and was afraid that he could not be, if he spent money so unnecessarily. The bridge, he thought, would probably be good enough anyway. If officials will not employ consulting engineers to advise them in the purchase of metal bridges, I cannot see how the present system can be very much improved.

I will, however, suggest a very simple measure which, if practiced, would probably have some tendency to improve the character of bridge construction. It is to require a cast iron name plate to be attached to each structure, showing not only the name and address of the contracting firm and date of construction, as is common, but also the guaranteed capacity of the structure, and either stating the factor of safety, or, what is better, naming the specifications under which it is constructed. If then the contract is let to a responsible firm that is actually engaged in the business of manufacturing bridges, the effect of the guarantee will be wholesome and the resulting structure will very probably have a capacity reasonably near, if not equal, to its guaranteed capacity.

A responsible company, owning a plant and expecting to

continue in the business of manufacturing bridges, would not be apt to construct a bridge, having an actual capacity of not more than, say, 1,000 pounds per lineal foot and bearing the statement: "Guaranteed live load capacity, 1,800 pounds per lineal foot, according to Cooper's Highway Specifications."

For at any subsequent time, and especially in case of failure, an expert could be employed to ascertain the actual capacity of the structure, showing the variation, if any, from the guaranteed capacity. This, however, would not greatly affect scalpers and irresponsible bidders.

It might also be quite effectual to require the guaranteed minimum weight of the metal work of each structure to be stated in each bid, and, finally, in the contract. This would be of assistance in comparing the bids, and, when the metal work is received at the railway station, it would not be a difficult matter to have it carefully weighed, thus making any material shortage apparent.

AMATEUR PHOTOGRAPHING.

F. HODGMAN.

When I was in college the subject of photography came up in connection with other studies. We were taught the principles underlying the art and a little of the manipulations required. We had no camera, so could not manipulate that or prepare our plates. That part we learned at long range without doing it. We did go to town and get our negatives taken and printed as many pictures from them as we chose. We prepared our own albumen paper and went through the various processes, and a motley lot of pictures they were when we were done. Few of them have lasted till now, and it is a wonder that any of them have. Later I spent a year in Northern New Hampshire, where I was every day in plain sight of the inspiring scenery of the White and Franconia Mountains. One of my most intimate friends there was the photographer, Kilburn. I spent a good deal of time in his gallery and was much interested in his work. Kilburn and I used to discuss, time and again, the possibility of preparing a dry plate which could be used in making stereoscopic views, which were just then coming into fashion. We believed it would come some day, but that it would be less sensitive than the wet plate and so require a longer exposure to make a picture. This notion cost me at a later day the loss of a great many pictures that I would prize most highly if I had them. After I returned to Michigan, Kilburn went into the view business and made a large line of views that for clearness and beauty of finish I have never seen surpassed and seldom equalled. I worked for a time in a photograph gallery and became fairly well versed in the old wet plate process, in which the plates were exposed from ten seconds to two minutes to get a picture. A dozen years later, I was engaged as engineer in the location and construction of the Rio Grande Western Railroad, in Castle

Valley and Wasatch Mountains, of Utah. Naturally I wanted to preserve mementos of the wonderful scenery through which I was daily passing, and began by a feeble attempt at sketching. But I had not time for that, not being an adept at it. About this time dry plates had been made a success and cheap outfits advertised for sale. I sent for one which reached me after a long and, to me, very vexatious delay. When it came I found I had a 4x5 camera with a Waterbury lens,—about ten boxes of plates, as many packages of sensitized paper and such implements and chemicals as were necessary to make pictures on a very limited scale. There was also a little book of instructions. I looked it carefully through and found but little in it that I did not know already; not a word about the time of exposure, which I imagined should be two or three times as long as for a wet plate.

I had no dark room and but one plate holder (a double one) so for a time I was limited to the use of two plates a day. The first night after the outfit came, I loaded my plate holder and the next day exposed the plates, giving them from 15 to 30 seconds exposure. When night came again, I had my developer ready, lighted my little red lantern, put out all the other lights in the tent, and went to work with the whole party gathered around, deeply interested spectators. I took a plate out of the holder, put it right side up in the tray and flowed it with the developer. The image quickly appeared and the details came out in a very short time. When it was developed as much as I had been accustomed to, I washed it and put it into the fixing bath. It was a long time in clearing and when it was cleared and washed there did not seem to be anything left of it but a clear plate of glass with a faint image on it. Both plates turned out pretty nearly alike, and I concluded that the exposure had been too short. I was surprised to find that I could obtain prints from these negatives, in which, by a liberal use of my imagination and knowledge of the subject, I could trace most of the features of the landscape photographed.

As long as my plates lasted I got nearly the same results, and vary the time as I would, from 15 seconds to a minute, out

of over 100 exposures I did not get one good negative and not more than a dozen that could be called passable. Most of them faded away entirely in the clearing process, leaving nothing to print from.

On my way home I went into an artist's room in Salt Lake City and asked him what was the matter. He did not know. He had never seen a dry plate. At Chicago I attended a photographers' meeting, when I presented the case and was told that I had exposed my plates a great deal too long and developed them as much too short. Dry plates are very much quicker than wet plates, and the development must be carried on not only till the details can be seen on the face of the plate, but until the high lights can be plainly seen on the back. There is little danger of developing too much. Plates that would seem to be hopelessly fogged from over development will often come out clear and strong from the fixing bath.

With these hints in mind, I came home and tried again with better success and have been making photographs at odd times ever since. For five or six years I lost more than half the plates I exposed. Part of this came from inability to judge correctly of the time for exposure, but mainly from an error which it took me a long time to learn—namely, that I was using too old developer. I would make up a batch when I wanted it and keep what I did not use until the next time, which might be three days or three months hence. I know now that I lost more plates from using old developer than I did from bad timing, although as a rule I over timed my plates. When the image would not come out as it should I laid it to short exposure instead of poor developer, which was the true reason. After a time I got a 5x8 camera, with an extra pair of lenses for stereoscopic views.

For a few years past I have lost but few plates, except by duplication. I usually make two exposures, giving different times, as it doubles my chances of getting a good negative. One is always better than the other. It is a little annoying when you have made an exposure on a subject which you never can have another chance at, to find that it has not been timed aright.

Perhaps it will be well to trace our way through the various operations to be gone through in making a complete photograph.

The first thing to do is to get your camera. I find a 5x8 inch, with the extra lens for stereoscopic views, suits me the best. Get the best camera box and lenses that you can afford for the work you want to do. They can be had at all sorts of prices. Some of the cheap ones do pretty good work—better than you would expect from the price. I have thrown aside the tripod which came with my camera and use the tripod to my light mountain Gurley transit instead. It works as well for the camera as it does for the transit. Get as many plate holders as you have use for and can afford. If you are miles from home and come across something you want a picture of, it is very annoying not to have a plate left for the purpose. It is worse yet, if you happen to have one, to find when you come to develop it that it is wrong side up in the plate holder or that you have put it wrong side up in the developing tray and stuck it fast there.

You will soon learn that to get the best picture a good deal depends on the point of view, and a great deal on the strength of the light and the direction from which it strikes your subject.

In out of door work you cannot arrange these things to suit yourself as you might in a gallery. You must select a point for your camera which will give the most pleasing view of your subject—or such a view as you want of it—and then watch for the time when the light is such as will best bring out its pleasing features. Sometimes you will have to get up pretty early in the morning for it. A person wants the soul and training of an artist to get the best results.

If you are making pictures right along you will be able to judge very closely how long to expose a plate and will not lose many from that cause. If you only take it up at long intervals, you will not be so sure of it. The plate makers say you should use a slow plate for out of door work, as it gives more latitude in the exposure without effecting the result seriously. I like better to use a quick plate, and get the same

result by stopping down my lens by using a diaphragm having the smallest practicable opening. With my cheap lens I get greater depth of focus and sharp outlines clear to the edge of the picture. With my lens thus stopped down I expose a No. 26 Seed plate from half a second to three seconds or more, according to the light. I have no shutter and guess at the time. At this point a good many amateurs stop business and hire a photographer to do the rest. I believe that every civil engineer should have a camera and know how to use it, and how to do everything connected with it, from loading the plate holder to mounting the print. When I built my office I put in a dark room. Before that I did all work, which required it, in the night by the light of a lantern with a red globe. That worked all right and does yet.

I have tried about the whole range of developers from oxalate of iron to eikonogen, with varied success, but the one developer which I always depend on is a pyro developer prepared from a formula which was published in the Scientific American some years since. It was such an easy formula to remember that I took to it at once. It is:

Bromide of Potassium,	1 grain	No. 1.
Pyrogallic Acid,	2 "	
Oxalic Acid,	3 "	
Water,	1 ounce	
Sal Soda,	50 grains	No. 2.
Water,	1 ounce	

Use equal parts of Nos. 1 and 2.

No. 1 should be used fresh or within a week or two after it is prepared. I have had good luck with some that was several months old by adding a little pyro to it. No. 2 will keep good till it is used up. I use about two ounces each of Nos. 1 and 2 to develop a 5x8 plate. If I have two plates to develop, I use the same developer for both, but do not like to use it longer as it gets too dark colored and stains the film too much. It gives the plate a reddish brown tint, which retards printing. For a thin, weak negative this is an advantage, as it will often make a good negative out of what would otherwise be a poor one, the effect being the same as an intensifier.

To develop a plate, take it in your dark room, if you have one, or at night by your red light. White light should never be permitted to touch a plate, except in the camera at the time of taking the picture, until development is well along or completed. Of course, your stock solutions Nos. 1 and 2 are already prepared. Take a sufficient quantity of each, mixing them well just before using. Put the plate film side up in the tray. If the plate gets wrong side up it is a goner. Pour the developer quickly and evenly over it, wetting the entire film at once. If this is not done you are liable to lose the plate by unequal development.

If everything is right the image will begin to show within a minute. If your room or developer is cold, do not be discouraged if it is a long time showing up. It may prove a good negative, but will take longer to develop. If the image flashes up very quickly, the exposure has been too long. After the film has been well wetted, the developer may be poured off and on, occasionally, to good advantage, as it seems to develop better when the film is in contact with the air, without any developer on it save what adheres to it. Continue the development until the main features of the image can be seen on the back of the film by reflected light. Then put the plate in clean water to wash off the developer, and from that into the fixing bath, which is made by d ssolving hypo sulphide of soda in water at the rate of about one ounce of hypo to four ounces of water. Let the plate stay in the fixing bath until you can see no traces of the white film when you look at the back of the plate—and a little longer. Then wash it in a dozen or so changes of clean water. I find that I get quicker and better results washing negatives, and prints too, by putting them in trays and changing the water on them every few minutes, than I do by letting a stream of water flow over them. The diffusion process is decidedly the quickest and does the best work. The hypo must be all washed out of the film or it will spoil the negative sooner or later, as well as damage the prints. When thoroughly washed, set the negatives up in a rack edgewise to dry. They must take their time for it without being heated. They will not stand heating over a stove as the old

collodion films would. It used to be the fashion to varnish the negatives when dry, and it is a nice little trick to do it well and not leave wrinkles. I can not discover that it pays me to do it. It certainly does not improve the printing qualities of the negative, although it may its durability.

Next comes the printing, and for this you must have printing frames to hold your negatives and sensitized paper to print on. There are many brands of paper on the market. They belong principally to three groups, the albumen paper, the gelatine paper, and the collodion paper, so called from the substances employed to coat the face of the paper for sensitizing. The latter varieties are sold in packages ready sensitized, any size you need, and all you have to do is to put your negative in the printing frame, film side up, then put a piece of the paper on it, film side down, clamp it in place and expose it to the sunlight a sufficient length of time. How long that will be depends on a variety of things, the negative, the strength of the light and the kind of paper. Generally speaking, they should be printed darker than they are to be when finished, as the tendency is to bleach out in the finishing. Some of the gelatine papers darken a good deal in the final drying after washing and will not bear so dark printing as others. If your negative is very thin, with plenty of detail, you will get a better and stronger picture to print it in the shade. Print from a dense negative in the direct sunlight. Do not expose the sensitized paper or the prints to the open daylight any more than is absolutely necessary, until they are toned and fixed. It makes all the difference between a clear, bright print and a dark, muddy one, whether you observe this or not. When you have a thin negative you can get a better print from gelatine paper than you can from albumen paper. Prints on gelatine paper are very fine when first finished. I am somewhat skeptical in regard to their durability.

Printing done, the prints are trimmed to the proper size for mounting. I use a sharp knife for this and glass patterns which I cut out myself. I find a sheet of pasteboard is a pretty good thing to lay prints on to trim them. When trimmed, put them in a dish of clean water, one at a time, face

downward, pressing them down under water as you put them in. You must have clean hands—clean trays and clean water for this, (soft water preferred) and no matter how clean your hands are, you should *never* put your fingers on the face of a photograph, either before or after it is finished. It is as certain to soil it as it would polished silver, and you can never remove the effects of it Collodion paper is not so easily soiled as the other papers. When your prints are well soaked take them out one by one and put them into a fresh dish of water and in that way wash them through half a dozen waters. If you are using hard water, the silver salt, as it is washed out of the paper, gives the water a milky color. Wash till all traces of it are gone. If you are using gelatine paper, the water should be cold, and in summer you may need to use ice to keep it cold enough not to dissolve the gelatine film. With collodion paper you can use warm water.

Toning is the next step. To do this put them in a bath containing chloride of gold. There are numerous formulas for the toning bath, as there is for everything else connected with the work, but I have succeeded best in this way: I dissolve a 15 grain bottle of gold chloride in four ounces of water, which I keep in a bottle for use as I want it. For toning I put enough water in my toning dish to nicely cover half a dozen 5x8 prints and give them a chance to float about in it. Then I put in enough of the gold solution to give the water a slightly yellowish tinge. It will not take much for that. Then I add a pinch of bicarbonate of soda, enough to make the bath distinctly alkaline. Put a few prints at a time into the toning bath, face down, and keep them moving or they will not tone evenly. Neither will they if not well washed beforehand. Keep watch of the prints and when they have attained the right shade and the details are well brought out, remove them to a dish of clean water. If you get a good tone, there must be a good strong print to start with—something for the gold to take to. You can't get a good tone on a thin, weak print.

The prints go next to the fixing bath, which consists of one ounce of hypo sulphite of soda to about 16 ounces of water and enough bicarbonate of soda to neutralize any acidity

of the bath—say half a teaspoonful. Put the prints in, face downward, and keep them moving so they will not pack together, and thus keep the hypo from getting at them. Fifteen minutes is about the right time for fixing. Then wash them, as directed before, through fifteen or twenty changes of water, letting them stay in each water from three to five minutes. When washed thoroughly they are ready for mounting.

Take them out of the water and pile them up, face downward, on a piece of smooth, clean oilcloth. Lay a piece of heavy blotting paper on top and squeeze or press the water out of them. You are supposed to have your cards ready for mounting, and some smooth, clean paste, free from grit or hard specks. Brush the paste smoothly over the back of the print, being sure to leave no part unpasted. Lift it carefully from the pile and place it on the card. Put another piece of clean, smooth oilcloth on top of the print, to keep your hands off from it, and then rub it down smooth and lay the picture aside to dry. If you are using gelatine paper, do not pile the pictures up after mounting or allow anything to touch the face of the picture while it is drying, or it will be glued fast.

THE HOLLY DRIVING TRACK.

GEO. W. DOANE.

The laying out and construction of a driving track is a subject in which we, as surveyors, are more or less interested, and one upon which very little has been written by surveyors and engineers.

It will be conceded that the best track for speed is a perfectly straight, level track; but, of course, this style of track is subject to the objection that the time cannot be noted by the same person, hence it is necessary to have a track on which the horses can start and finish at the same place.

The rules of both the American and National Trotting Associations require a track to be one mile in length, three feet from the pole. There are no regulations in regard to shape. On what is known as a regulation mile track, the stretches and turns are equal in length; that is, 1,320 feet each.

In the construction of a regulation mile track 66 feet wide, it will require a rectangular area of about 52.5 acres, and for a half-mile track 50 feet wide, it will require a rectangular area of about 10.75 acres, exclusive of ground for grand stand, stables, etc.

The surface area of a mile track 66 feet wide is about 8.3 acres. The surface area of a half-mile track 50 feet wide is about 3.2 acres, or less than 40 per cent. of area of a mile track.

It will be seen that the half-mile track can be built for much less cost than the mile track and hence its desirability for small towns.

In a race against time, the mile track has the advantage in longer turns, and requiring less elevation than the half-mile track, to attain the same speed. On the other hand the half-mile track is liked better by some because they can see the horses start and finish, and also pass the grand stand in the middle of the race.

In the spring of 1893 I was called upon to lay out and construct a half-mile driving track for the Holly Driving Club.

After making inquiry and visiting a couple of tracks and examining the ground upon which the track was to be located, I recommended a track with two parallel tangents 600 feet in length and a semicircular arc of 720 feet at each end, and having a radius of 229.2 feet to the half-mile line, and 50 feet width of track; which plan was accepted by the club.

The track was located on a piece of ground containing 26 acres, about one-half mile northwest of the village of Holly, and between the Shiawassee river and Bevins lake, on a slight ridge. The track was located lengthwise of this ridge. The soil, except the north turn, which was a light sand, was a gravelly loam which made a very good track, but the north turn had to be dressed with heavier soil.

The system adopted in laying out the track was as follows: After some preliminary measurements, two hubs 3x3 and three feet in length were driven to the surface of the ground and a wire nail driven in each at the exact point of the center 600 feet apart. The tangents were located by placing a transit over one hub and exactly perpendicular to the line joining the two center hubs and measuring 226.2 feet for inside, and 276.2 feet for outside tangents. Stakes were then set ten degrees apart on the turns by angles taken at the center, making them 39.47 feet apart on the inside, and 48.2 feet apart on the outside of the track. We then went through the same procedure at the other turn.

Stakes were then set on the tangents 50 feet apart and numbered.

Then we were ready to take the levels, which we did by placing the level in the middle of the ground and taking a reading at each of the stakes; making benches of the two center hubs so that any stake that might be lost could be easily relocated from the center hubs. After which a profile was made and a grade established.

Owing to the unevenness of the surface of the ground, we found it necessary to make a grade, on the inside, of 15 feet for the first half length of the track and the same on the

return. This is, perhaps, more grade than is desirable, but owing to the extra cost in building a level track, this was thought best.

The outside of the track was raised six inches higher than the inside on the stretches, to give drainage, and forty-eight inches higher on the turns.

On the outside the rise was begun at a point 50 feet from the turn, on the stretches, and carried with a true grade until it was full height at 50 feet past the turn on the curves.

The drainage of the track was comparatively easy. A six inch tile was laid from the low lands on the west side of the grounds, and was laid across the track at the southwest turn, where a catch-water basin was put in to receive the water from the open drains laid along the inside of the track; and from there a three inch tile was laid across the grounds to the east turn to receive the water from the open ditch along the track.

The earth was moved with wheel scrapers on the longer hauls and drag scrapers on the short ones.

The cuts nearly made the fills at the south end, and surface soil was taken from the inside of the track to complete them. At the north turn the earth that was not used in making the fill was wasted, as it was too far to haul to where it was needed and unfit for track surface. The north turn was covered with surface soil from the south end of ground.

The track was packed and leveled by the use of a harrow and float. The float was made of eight pieces of 2x4 scantling bolted together so as to form a float sixteen feet square which was drawn by four horses.

We first tried a road grader for leveling the track, but its use was very unsatisfactory and was abandoned.

After the track was thoroughly leveled and packed down, the small stone were raked off by hand with fine tooth rakes prepared for that purpose.

The inside fence was then built by setting posts eight feet apart and about forty inches high, with a guard board ten inches wide, nailed on about twenty-three inches above the ground, and a 2x4 scantling spiked to the top of posts. We then carefully measured the fence with a 100-foot steel tape,

along the guard board. Each tangent 600 feet, the south turn 710.57 feet, and the north turn 710.6 feet, making a total length at the fence of 2,721.17 feet. Add to this 18.85 feet for the length of the half mile line three feet from fence and we have 2,640.02 feet for the length of track.

The judges' stand was placed on the stretch 100 feet from the southwest turn.

The cost of track and buildings is about as follows:

26 acres of land at $50	$1,300
Grading and ditching	600
Judges' and grand stand	426
50 stables at $12	600
Total	$2,925

There has been expended since completion about $300 in top dressing with clay loam.

The track has given good satisfaction to the club and is highly spoken of by horsemen.

Q. Do you know whether any of these associations have by resolution, or otherwise, fixed the maximum grade?

A. I believe there is nothing said in regard to grade of tracks.

Mr. Doane.—I don't know as there is any fixed rule, but it is a recognized rule among horsemen that the road shall rise one inch to the foot; a track is not disqualified, no matter what the shape is, provided it is not too short.

Mr. Rogers.—I don't know whether other people have had the experience we had at Port Huron. Last year I was called upon to reduce the elevations on a track which had been satisfactory; they said the reason for reducing the elevations was on account of the use of pneumatic tires on the sulkey. I did not lay out the track, but the elevation was one in ten before it was reduced, and it was cut down so that the elevation was not more than a quarter of that.

Mr. Doane.—I corresponded with the Secretary of the Detroit Driving Club. He said they had built a track there with tangents; I suppose they used the easement curve, and he said they used an elevation of one inch in twelve.

Mr.————.—The Terre Haute track is what might be termed a square track. There are four straight stretches, and the curves are divided into four parts, and it is one of the fastest tracks in the United States.

Q. Do you know the radius of the curve?

A. I don't know, but about the same as in a half-mile track. It is a mile track divided into four straight stretches. The theory is that the straight stretches change the gait of the horse slightly and it gives him a rest; while he passes the curve he is only there a short time until he is on the straight stretch. It gives him four changes in going around,—whereas the long curve only gives him two.

WHAT CAN BE DONE WITH THE WASTE PRODUCTS OF OUR LUMBER WOODS.

J. J. HUBBELL.

The lumbermen of Michigan purchase their timber by the tract or group. It is true the location is indicated by certain description of land, but the land itself is a very small factor in the transaction, the timber is what the lumberman purchases, and when he is ready to cut the same, he enters upon the lands and cuts, carries away, and converts to his own use, as much of the timber as he thinks he can handle with profit; the remainder of the timber is left standing or lying upon the ground, and it is this remainder which is allowed to go to waste to which I wish to call your attention at this time.

A personal examination of cut lands in Michigan will reveal the fact that a very large percentage of the timber is allowed to go to waste. I am satisfied that in the cutting of pine timber this waste will amount to 40 per cent. of the original forest growth, there being usually a considerable amount of beech and other hard woods, as well as hemlock and cedar, mixed with the pine, a large proportion of which is never cut. I am also satisfied that the proportion of waste in the cutting of hemlock and hard woods will amount to nearly if not quite 60 per cent. of the original forest growth, and that, as a whole, in the cutting of timber in Michigan the amount taken away, and made use of, does not exceed one-half of the amount originally standing upon the lands.

This timber that is left consists largely of beech (of which at the present time very little use is made), also maple, elm, birch, black ash, cedar and hemlock, which, for reasons that it will not float, or it is too expensive to get it out of the swamps, or for some other reason, cannot be handled with profit; also defective trees, dead stumps, tops and limbs.

It requires some figures to call to our minds an approximate idea of the vast amount of this waste product. I have not been able to secure close estimates of the amount of timber cut in the State of Michigan annually, but from what data I have been able to secure, I have estimated that it amounts to 1,200,000,000 feet (board measure) of pine, 400,000,000 of hemlock, and 400,000,000 feet of hard woods, making a total of 2,000,000,000 feet. I am also satisfied that the way logs are scaled in Michigan, one thousand feet of logs will make one cord of wood. If this is true, we leave standing and lying upon the ground to go to waste yearly, the enormous amount of timber sufficient to make over 2,000,000 cords of wood. Commence piling this wood upon the Atlantic Coast in the State of New Jersey and pile westward one cord high in a continuous rank, and it would reach across the State of New Jersey, across the State of Pennsylvania, also Ohio, Indiana, Illinois, Iowa, Nebraska, Colorado, Utah, Nevada, in fact, well nigh or quite to the Pacific Ocean, in other words, two million cords of wood will make a continuous rank over three thousand miles long. As compared with coal, if we allow three cords of soft wood, or two cords of hard wood, as equal to one ton of coal, we have the fuel value of this waste product equal to 733,000 tons of coal. The money value of this waste product computed in wood at $1.00 per cord, or in coal at $3.00 per ton, we find to be over two million dollars.

I am aware that these figures will seem to many of you as exaggerated, but I only invite you to figure the problem for yourselves, and whether your computations fully corrobate my figures or not, you will arrive at a result which will satisfy you that there is an enormous waste of material going on at the present time in the State of Michigan.

What becomes of this waste product? In some sections there is an effort made to get out a small quantity of cord wood, there are a few coal kilns scattered throughout the State, but all the wood manufactured from this product is an insignificant amount compared with the total waste. The great mass of this timber left standing and lying upon the ground is destroyed by fires, and the burning of the same is

usually left to chance. The fires usually take place in time of drouth, and not only destroy the waste product, but often do great damage to the uncut timber standing adjacent, and also to farm and village settlements throughout the northern part of the State. The first fire of a chopping not only burns the brush and tops of the cut timber but also kills the remaining standing timber, also the young second growth timber with which nature attempts to re-clothe the ground. This dead timber in time blows down, the dead underbrush and limbs of the fallen timber make kindlings and fuel for a second fire, which is frequently followed by a third, and sometimes a fourth burning. These repeated burnings, usually occurring at times of drouth and extending over a period of eight or ten years after the original chopping, result in leaving the land in a most deplorable and desolate condition, the leaf mold and soil itself being largely consumed, the fires enter the swamps and burn their way several feet in depth into the dry, mucky soil, all second growth of timber is repeatedly killed. In addition to this, the ground being bare and exposed, evaporation is largely increased, and the effect upon the moisture and rainfall is evident from the greatly diminished flow of water in our rivers and the lowering of the surfaces of our great lakes. So we see that the loss of so large a percentage of our forest growth is only the beginning of loss, incident to our present method of lumbering and the neglect of the care of the waste product.

From a legal standpoint of view, there is no question but that lumbermen have a right to cut and use as much of their timber as they please, and to leave for destruction as much as they see fit, but when viewed from an economical or a moral point of view, grave questions arise as to the right of any class of men to entail such waste and desolation upon the land and the future prosperity of the people and State. Older countries than ours have long since learned the evil of permitting the indiscriminate destruction of their forests and strict laws regulate the cutting of timber, and provide for the perpetuation of suitable forest growth. The indifference of the American people upon this question I attribute largely to the fact

that from the first settlement of the country until the vast prairies of the west were reached our forefathers were confronted with a dense forest growth, which stood in the way of the improvement and cultivation of the land; and we have waged for generations a relentless war with axe and torch upon our virgin forests until we have well nigh lost all our respect or reverence for a healthy forest growth which it has taken nature a century or two to perfect. I apprehend it will take a considerable time, a long and earnest effort upon the part of economists, before the American people will recover from their present apathy and indifference upon this subject. But, to return to my topic, what can be done with this waste product? The first answer would naturally be that the lumbermen should be compelled to take care of it, and yet I apprehend that any steps taken in this direction must be well considered and that radical measures would be disastrous to the best interests of our state and our people. Our lumbering interest is one of the greatest, our lumbermen the most enterprising of our citizens; they give employment to an army of men; they are conducting their business in compliance with the laws of trade and of supply and demand. They are no more vandals, or more selfish than other men; they are deeply interested in the preservation of our forest; it is largely their property and their future stock in trade; they are interested in preserving the fertility of the soil; it is their land after being cut over and if they ever realize anything for it, it will be on account of its value for agricultural purposes; they are interested in securing a second growth of timber, and maintaining the waters of our rivers and lakes, they are their principle means of transportation; no class of men are better acquainted with the evils of which I speak than they, and I am satisfied that as a class they will heartily join in any practicable measures to remedy the same, a large proportion of them, however, are carrying on business upon a very small margin of profit. While it is true that certain older operators may have purchased their timber at a nominal value, a large proportion of the present lumbermen have paid full value for the timber, expecting to cut and market the same without being put to undue expense other

than that which is usually incurred in lumbering operations, and any steps taken in the direction of compelling them to take care of this waste product must be reasonable and well considered. If the process of destroying by fire is to be continued I wish to suggest:

First—That the lumberman be required to cut down all of the timber upon his cut lands. This can be done at the time, soon after the merchantable timber is cut at a small expense. To leave this timber standing is not to save it, it eventually falls a prey to the fires, but if cut in the first instance it would have a tendency to make a more thorough work of the first fire and put a stop to the second, third and fourth burnings.

The second suggestion that I would make, is that all choppings should be burned over the first spring after cutting, during the month of May. It is well known that at this time of year, before the green forest growth begins, fires burn readily, at the same time they do not burn deep, and do not enter the swamps and mucky ground. Fires at this time of the year do but little damage to the surrounding timber and seldom are destructive to farm and village settlements. If all the timber was cut down and choppings burned at this time of the year, there would be but little danger of subsequent fires, and in most instances the second growth of timber would be unmolested and have an opportunity to reproduce a second forest growth. Whether this annual burning should be left to the lumbermen to do under penalties, or whether it should be done by township or county officials, is a question for future consideration, but is it necessary to continue this destruction by fire? As engineers, I would say that it should be our aim to utilize and make use of this waste product, rather than to attempt by legislative enactment to direct and control its destruction; as engineers we should exert ourselves to save this vast amount of timber which is at the present time going to waste, to provide for better and cheaper means of transportation, to encourage the use of wood as fuel, to devise improved methods of handling wood, manufacturing charcoal, wood alcohol, paper pulp, and other products, anything to make a profitable use of this material rather than waste and destroy it.

The waste materials of other productive industries have often been found to be valuable and to add material profits to the industry. It was finally discovered that the despised and troublesome cotton seed contained oil as palatable and nutritious as the olive. Our timber going to waste contains potash, creosote, wood alcohol; it contains light, heat and power, all of which have a commercial value in the world; we should endeavor to devise ways and means whereby they can be made available for the use of mankind, and then we shall no longer be troubled with the question as to what to do with the waste product of our lumber woods.

Mr. Hodgman.—It is a paper that does not leave very much room for discussion, except to endorse what the gentleman has said. He has opened up a very important subject—one of the most important that we find to consider, but I don't know what we can do except to go at it and educate the people, and do the best we can.

The President.—Mr. Hubbell, is it not a fact that where pine timber grows mixed, or where it grows of such size that part of it is left for a future harvest, if the cutting away of a mass of that timber and allowing the sun to come in and evaporate the moisture which was before held in the leaves and twigs and earth, if the pine timber which is left is not likely to die for want of water, even where the rainfall is ordinarily good?

A I think pine is one of the best timbers to partially cut and partially leave, if you can only keep the fire out. Pine trees almost entirely isolated will live and grow. It is not so with hemlock; that will die, but with pine timber which has been partially cut, it is not the question of drouth, but the fire which almost inevitably comes in and kills it.

The President.—I have made one or two trips from Michigan to the Atlantic coast, at some expense, to fight wood creosote, and there is this important point about creosote which Mr. Hubbell has mentioned. Creosote does exist in wood, and in coal, which is a geological formation of wood; it has been found that creosote obtained from the distillation of wood is largely impregnated with acetic acid. In the use of

creosote from wood in preserving timber, it has been found that where it comes in contact with metals, that the acetic acid with which it is impregnated, will attack and destroy the metal and cause much damage. It treating timber that ought to be remembered, because it has involved a great deal of loss.

Mr. June.—I would like to ask if Mr. Hubbell has ever had any experience in measuring the per cent. of value in the growth of pine timber?

Mr. Hubbell.—No, I have never figured it out; I know in a healthy pine growth, it is pretty well established that the growth will keep ahead of 6% interest and ordinary taxes, but if your timber gets burned off, you are of course a loser.

Mr. June.—I was talking once with Mr. Farrell, who has some interests down south. He says that the pines are not as good as in Michigan, but he thought the growth there was as good as 10%. Mr. Webster of this city had some trees up at Gladwin, which he measured and watched, and he made the statement that they were as good as 10%.

Mr. Hubbell.—In that connection, of course, you have got to figure 10% on what you have to pay for the timber. In Michigan, at the present time, pine stumpage has come to such a point that it would take pretty good pine to come up to that.

Mr. June.—The trees that I speak of, were trees that were left, and a second cutting.

Mr. Appleton.—If the members wish to pursue the subject of forestry, I have found that the agricultural department at Washington publish a report, by Mr. B. C. Furnow, Chief of the Forestry Division, which can be had for the asking. Mr. Furnow is an enthusiast on this subject.

The members will find a great deal of valuable information in that. The State Department also publishes a special Consular Report on Highways in Foreign countries, which bears on this subject, and besides gives very complete specifications of various methods of constructing highways in Europe, and, proud as we are of our Yankee accomplishments, we must bow to our European brothers in the construction of highways, and much valuable information can be had from them.

IMPROVEMENT WORK ON THE ANN ARBOR RAILROAD.

BY MR. RIGGS.

I wish to state that in writing to the secretary and notifying him that I would give a paper, I tied a string to my letter and said I would do so provided I could find the time. As most of you are well aware, I am severing my connection with the road, and opening a business, and for the past sixty days I have hardly seen home, so that you will have to bear with a few very rough notes, and I will merely outline what work the T. & A. road has done and invite a full discussion.

I believe that possibly better results can be reached by answering questions than by undertaking to give any lengthy paper.

The problem of Railroad Construction will in the future occupy much less of the attention of the Engineering profession than in the past, while the question of economical maintainance, and of construction of old lines, placing them on a basis where they can be economically operated, will demand more attention.

The tendency of the times is toward a greater amount of legislation on the railroad question. Legislation and competition, with a number of other causes, are constantly working to lower the rates of freight, that sadly cuts the revenues.

The smaller lines of railroad throughout the country were built frequently on limited means, and without particular attention to economy in grades or curvation; often were constructed to take care of a limited local traffic, but by extensions undreamed of by the original projectors, or by connection, were forced to handle a much greater volume of business than was calculated upon.

Such lines of road, when brought face to face with the problems of reduced rates and decreased earnings, must meet

the question of either increased power, reconstruction on more economical lines, or must admit failure and cease to operate.

Larger and more powerful locomotives have been tried. For a poor road that means an immense increase in the wear and tear of all track structures and the ultimate reconstruction on a heavier and more substantial scale.

Still, other lines have retained the old class of power, and by reducing grades, have increased the hauling capacity of their trains.

Perhaps no line in the State of Michigan better illustrates the class of road referred to than the Ann Arbor Railroad, formerly known as the Toledo, Ann Arbor and Northern Michigan Railway. It was built under the most discouraging difficulties, without money; simply on wind. Its projector had at all times faith that he could push it across the state and make a good road of it, and after years of work he has done so.

No definite plan was worked out before construction was commenced. The road started at Toledo, and went northwest. It was a local road, pure and simple, for years. The North end was constructed cheaply as possible, to handle the lumber traffic of a practically limited territory.

A dozen different engineers located various short sections; nearly as many small companies contributed to build it. Old grades were utilized, abandoned logging roads were seized upon and used for miles; when any considerable length of line was to be built, it was generally undertaken with a small supply of cash and a large supply of courage; grades were changed to reduce the amount of yardage, and every expedient adopted that would permit the company to operate trains in season to secure bonds.

In 1892, the ferry line across Lake Michigan was put in operation; from a local road it became a through freight line, and was forced to compete for traffic with older and better located roads.

At this time its grades were exceedingly heavy (nine loaded cars being all that could be carried at several points); its track was bad by reason of poor ties and no ballast; its bridges old and poor, and the road was in generally bad condition.

A general plan of improvement was decided upon and has been carried out nearly to completion.

This plan has involved the expenditure of a large amount of money and an immense amount of work. It is not my intention to do more than roughly outline the work which has been done and call attention to a few statistics of steam shovel work, which appear to me to be of great interest to Engineers, who will, in the future, be called upon to undertake work of a like character.

In the matter of bridges, the company has a large number of pile trestles and comparatively few permanent structures. The work of filling or renewing has been carried on with the following result:

28 new bridges have been built as follows:—

2656 lineal feet of deck plate girder; 190 feet of three plate girder; 115 feet of steel deck truss and three 20 feet I beam spans, or a total of 2906 feet of permanent opening established.

On all of this work, excepting that done prior to 1894, (or on about 90%) a load has been specified as Cooper's Class Extra heavy A, with impact of 25% on spans of 20 feet, and less, decreasing at a rate of 1% per four feet of increased length.

116 bridges have been filled and 12 have been shortened—a total opening abolished of 5796 feet. Cast iron pipe has been used largely, and for smaller openings, Blackmer and Post's double strength culvert pipe has been used. In marshy or treacherous bottoms a floor of grillage has been constructed as foundation for pipe culverts.

Concrete piers encased in steel cylinders have been put in River Raisin bridge at Dundee.

The bridging is in safe condition and all of the larger permanent openings are built so that it is safe to say that 75% of the superstructure work is done.

The foundations so far have generally been piling, but in every case the future masonry pier or abutment has been figured on, and a sufficient number of piles driven for a foundation for this work.

A comparatively small amount of work was required on buildings. The station buildings being generally in good condition; four new round houses and a few stations rebuilt being the principal work.

Yard room was greatly increased by the construction of complete and well arranged division yards at Toledo, Durand, Mt. Pleasant, Cadillac and Frankfort, and by the construction of a considerable mileage of additional sidetracks at other stations. This work has greatly facilitated the handling of traffic.

A large amount of work has been done in the way of eliminating curvature or grades by changes of line.

The most important work of this class has been done in Clare County, where for several miles an old logging road was used. Some six miles of entire new line eliminates over 200° of curvature as well as reduce a heavy southbound grade from 2% to 0.75%. Other minor changes have been made, aggregating some five miles in distance and greatly reducing curvature.

The most important work of this sort is the contemplated change of line north of Ann Arbor, which will abandon ten miles of line. The original intention was to build a road from Ann Arbor, via South Lyons and Pontiac to the north. After a part of this had been built, a branch was constructed from Emery, seven miles from Ann Arbor, to Whitmore Lake and Hamburg. The line to South Lyons was subsequently abandoned, and the branch is now main line.

The new line has the following characteristics:—

It saves 2.382 miles in distance.

It saves 244° 46′ of curvature.

It saves 1.57 miles of actual curved line.

It has a north bound rise of 155 feet, as against 245 on the old line, saving 90 feet.

It has a south bound rise of 48 feet, as against 138 on the old line, saving 90 feet.

It has 15,500 feet of 0.75% (40 feet) maximum grade, as against 19,300 feet of 1% and over in the old line, with a maximum of 1.5%.

It has 4,600 feet of 0.75% (30 feet) maximum south bound grade, as against 10,100 feet of over 0.75%, with a maximum of 2% on the old line.

This line will probably be built during the present season, and will greatly improve the road in its ability to handle north bound business as well as greatly increase the safety of the line.

By far the larger part of the work done during the past three years has been toward establishing a uniform system of grades. An outline of the plan, and the submission of a few figures is all that can be done.

The new scheme contemplates grades as follows:—

North bound maximum grades—Toledo to Clare, 20 feet per mile, except at Milan, where trains will double 1 mile, and at Ann Arbor, where a pusher will be maintained. Clare to Frankfort, $52\frac{8}{10}$ feet per mile.

South bound maximum grades—Frankfort to Cadillac, 65 feet per mile. Cadillac to Clare, 40 feet per mile. Clare to Toledo, 30 feet per mile.

Next season's work will complete all work on this plan except possibly one or two south bound grades between Cadillac and Frankfort. All of this work has been done by the company. They have used steam shovels of various patterns, all having 1½ yard dipper, and having used Barnhart Center Unloaders, plowing with engine.

The past season has been one of greatest activity, six shovels being at work, and for a greater part of the time we have worked both day and night shifts.

This fact has rather impaired the value of our statistics, as all of our measurements are based on actual pit cross sections, and it was absolutely impossible to separate day and night work. In making up the statement, a night's work is counted as a day, thus affecting the average hourly output of the shovel. Another feature of uncertainty is the fact that the number of locomotives in attendance on the shovels varied from time to time, and the record of such movements was very difficult to keep.

The additional fact that no form of report was used, all data being compiled from daily telegraphic reports, made it impossible to secure as complete a record as was desired.

With this general outline I would submit the table of cost. All figures represent cost of earth under the track, including all labor of shovel crew, train crew and track men, fuel and supplies, but do not include any figures for rental of plant, repairs or any charges for service of telegraph, station or other employees; nor do they include engineering or superintendence (other than foreman).

It is to be regretted that there is not more literature on Steam Shovel work, the work of Mr. E. A. Herrmann, in *Engineering News*, some two years ago, being the most complete discussion I have seen. Records of cost of such work, however, are rare, and these are the most valuable information that can be had, for anyone about to begin work of this nature.

The Steam Shovel and its relation to railroad reconstruction has been but little discussed. This machine has a great future of usefulness in the work of railroads, as will be seen by the work done on the Ann Arbor Railroad.

ANN ARBOR R. R. Steam Shovel Exhibit, Season of 1895.

LOCATION AND DATE.	Total Car Loads	Total Cu. yds	Aver'ge yds. per car.	Total Time, Days.	Aver'ge Car l'ds per day	Aver'ge Cu. yds per day	Actual Time of Shovel hrs	Aver'ge Loads pr. hour	Aver'ge Cu. yds pr. hour	TOTAL COST.	Cost per yd. Under Track.	Character of Material.	REMARKS.
SHOVEL No. 1 (BUCYRUS S. S.)													
Millersville ..... April 3 to June 20	6676	55934	8.37	68	98.19	822.56	.....	.....	.....	$5509 59	$0.0984	Sand	.....
Harrietta ..... June 20 to July 13	2164	20017	9.25	19	113.90	1053.52	.....	.....	.....	1773 35	.0886	Sand	.....
Pittsfield ..... July 15 to Aug. 31	4913	32928	6.70	59	83.27	558.10	.....	.....	.....	4377 61	.1331	Clay	.....
Ann Arbor ..... Sept. 2 to Sept. 29	2362	16910	7.16	46	51.35	367.61	.....	.....	.....	3355 64	.1981	Gravel	Long Haul.
Milan ..... Sept. 30 to Oct. 24	2490	23527	9.45	44	56.60	534.70	.....	.....	.....	3266 29	.1388	Sand	.....
Monroe Junction ..... Oct. 25 to	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Sand	Long Haul.
SHOVEL No. 2 (BUCYRUS S. S.)													
Farwell, 1st Cut ..... April 1 to May 14	5028	31786	6.32	38	132.31	836.47	259.83	19.35	122.33	3095 04	.0973	Sand	.....
Clare Clay Cut ..... May 15 to June 21	3112	16415	5.27	31	100.39	529.52	200.50	15.52	81.87	2897 78	.1765	Clay	Hard Pan.
Farwell, 2d Cut ..... June 22 to July 29	3176	29373	9.24	32	99.25	917.90	195.50	16.24	150.24	2609 55	.0908	Sand	.....
Clare Sand Cut ..... July 30 to Aug. 7	1359	8476	6.24	15	90.60	565.00	85.50	15.89	99.13	827 59	.0978	Sand	.....
Lake George ..... Aug. 7 to Sept. 18	4518	39724	8.79	66	68.45	601.88	323.50	13.96	122.79	4160 13	.1049	Sand and Clay	.....
Clutes ..... Sept. 19 to Sept. 29	1205	13260	11.00	19	63.42	697.90	71.66	16.81	185.04	1354 12	.1021	Sand	.....
Temple Clarence ..... Oct. 2 to Nov. 2	2309	17652	7.64	40	57.72	441.30	123.66	18.67	142.74	2815 33	.1595	Quicksand	.....
Temple, 2d Cut ..... Nov. 3 to Nov. 12	1124	9788	8.70	16	70.25	611.25	57.75	19.46	169.49	803 97	.0821	Sand	.....
Howell Gravel Pit ..... Nov. 14 to	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Gravel	.....
SHOVEL No. 3 (MARION S. S.)													
Samaria ..... April 8 to April 20	717	6114	8.53	12	59.75	509.50	57.00	12.58	107.27	651 17	.1065	Sand	.....
Howell Fair Grounds ..... April 22 to July 17	5570	36514	6.56	74	75.27	493.43	414.33	13.44	88.12	5117 89	.1401	Clay	.....
Howell Junction Gravel Pit ... July 18 to Aug. 2	2239	15905	7 10	33	67.85	481.97	115.50	19.37	137.70	2286 44	.1437	Gravel	.....
Pettysville ..... Aug. 2 to Aug. 27	1314	10233	7.78	21	62.60	487.30	114.25	11.50	89.56	1430 56	.1398	Quicksand	Very light face
Sexton's Cut ..... Aug. 28 to Sept. 23	1703	14175	8.04	34	51.85	416.91	126.33	13.95	112.20	2444 29	.1724	Sand	.....
Howell Junction Gravel Pit ... Sept. 24 to Oct. 1	627	.....	.....	14	44.78	.....	45.50	.....	.....	.....	.....	Gravel	.....
Chilson, at Station ..... Oct. 1 to Oct. 4	302	2231	7.38	7	43.14	318.71	26.67	11.32	83.65	386 12	.1731	Sand & Gravel	Very light face
Howell Junction, 1 mile south. Oct. 5 to	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Clay	.....
SHOVEL No. 4 (MARION S. S.)													
Samaria, South of ..... April 22 to April 26	325	3595	11.06	5	65.00	719 00	21.83	14.88	164.68	914 66	.2544	Sand	All work lowering by hand chgd. against this cut.
Temperance ..... April 27 to May 29	2874	23571	8.20	28	102.64	841.82	133.75	21.49	176.23	2546 62	.1080	Sand	
Pittsfield ..... May 30 to July 12	3058	24378	7.97	37	98.70	658.86	174.17	17 56	140.00	2339 98	.0960	Clay	
Churchill ..... July 15 to July 27	1184	7938	6.70	12	98.67	661.50	44.00	26.91	180.41	1074 20	.1353	Sand	
Bagnall ..... July 29 to Aug. 12	1788	16450	9.20	23	77.74	715.20	82.20	21.75	200.21	1066 63	.0648	Sand & Gravel	.....
Dairs Creek ..... Aug. 12 to Aug. 21	1026	8897	8 67	15	68.40	593.13	58.40	17.57	152.34	872 65	.0980	Sand	.....
Betsey River, north } Aug. 21 to Aug. 30	3152	32489	10.30	32	98.50	1015.28	156.58	20.13	207.49	2444 31	.0722	Sand	.....
" " } Oct. 21 to Nov. 5													
Crystal Lake Outlet ..... Aug. 31 to Sept. 21	2181	20244	9.28	37	58.95	547.13	130.66	16.69	154.93	2384 86	.1178	Clay	.....
" " ..... Sept 23 to Sept. 30	834	16258	7.52	13	55.60	481.38	55.53	15.02	112.69	829 70	.1325	Sand	Light face.
" " ..... Oct. 1 to Oct. 12	1164	13096	11.22	19	61.26	687.68	73.17	15.90	178.57	1166 86	.0893	Gravel	.....
Betsey River, south ..... Oct. 13 to Oct. 20	835	8851	10.60	14	59.64	632.21	56.00	14.91	158.05	777 90	.0879	Sand	.....
Frankfort ..... Nov. 6 to Nov. 12	562	4999	8.90	10	56.20	499.90	27.50	20.44	181.77	578 19	.1156	Sand	.....
Homestead ..... Nov. 13 to Nov. 17	495	4814	9.72	9	55.00	534.89	22.91	21.60	210.12	412 99	.0858	Sand & Gravel	.....
" 2d Cut ..... Nov. 18 to Nov. 26	595	5070	8.46	14	42.78	362.14	35.56	16.84	142.55	743 58	.1269	Sand	.....
Temple ..... Nov. 27 to	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	Quicksand	.....
SHOVEL No. 5 (MARION S. S.)													
Dickinsons ..... May 14 to June 20	1549	14630	9.44	19	81.53	770.00	.....	.....	.....	1747 65	.1194	Clay	.....
Park Lake ..... June 21 to Aug. 4	3601	39919	10.24	39	92.33	946.64	.....	.....	.....	3775 61	.1022	Sand & Gravel	.....
McBain ..... Aug. 5 to Aug. 9	505	4009	7.94	10	50.50	400.90	.....	.....	.....	410 04	.1022	Clay	.....
Cadillac ..... Aug. 10 to Sept. 1	2504	24152	9.64	31	80.77	779.10	.....	.....	.....	1931 00	.0800	Clay	.....
Lucas ..... Sept. 2 to Oct. 31	6905	66503	9.98	102	65.34	652.58	.....	.....	.....	7250 60	.1089	Sand	.....
SHOVEL No. 6 (BAY CITY IND.)													
Durand ..... July 22 to Sept. 21	4295	35206	8.20	84	51.13	419.12	.....	.....	.....	5044 38	.1432	Clay	.....
Oak Grove ..... Sept 24 to Oct 2	499	3500	7.01	13	38 39	269.23	.....	.....	.....	1076 26	.3075	Clay	.....

TOLEDO, ANN ARBOR & NORTH MICHIGAN RAILWAY.

W. R. BURT, RECEIVER.

Exhibit of Steam Shovel Work, Season of 1894.

LOCATION AND DATE.	TOTAL CAR LOADS.	TOTAL CUBIC YARDS.	Average yds. per Car.	Total Time Wrk'd, Days	Average Car Loads per Day.	Average Cu. Yards per Day.	Net Time Wrk'd, Days	Net Average Car Loads per Day.	Net Average Cu. Yards per Day.	TOTAL COST.	Av'ge Cost per yd., Cts.	REMARKS.
SHOVEL NO. 1.												
Yuma.....April 12 to May 21	4200	34706	8.26	37	113.50	938.0	25.60	164.06	1355.0	$ 3655.16	$10\frac{53}{100}$	Sand; Short Haul.
Park Lake...May 21 to June 29	2759	23185	8.40	34	81.14	681.9	21.23	130.00	1092.0	2912.82	$12\frac{56}{100}$	Gravel.
Dickinson's ..June 30 to Aug. 6	3559	20655	5.80	31	114.81	666.0	23.87	149.10	865.3	3280.22	$11\frac{04}{100}$	Clay. long haul.
Lake George.Aug. 7 to Oct. 3	4143	30428	7.34	48	86.31	633.9	28.66	144.56	1061.6	5118.78	$16\frac{82}{100}$	Sand. Clay, Quicksand,
Howell Gravel Pit...Oct. 9 to Nov. 23	2898	25731	8.88	44	65.87	585.0	23.87	121.40	1078.0	4403.71	$17\frac{11}{100}$	Long Haul.
	17559	134705								$19392.79		
SHOVEL NO. 2.												
Oak Grove...April 2 to May 19	3911	26681	6.82	42	93.12	635.2	28.88	135.42	923.80	$ 3657.05	$13\frac{70}{100}$	Sand and Clay.
Pettysville ...May 20 to July 19	4512	31801	7.05	50	90.24	636.1	32.00	141.00	993.80	4782.32	$15\frac{03}{100}$	Cost Divides with
Howell Gravel Pit...July 20 to Aug. 8	1947	13527	6.95	17	114.53	795.7	11.55	168.57	1171.20	1508.32	$11\frac{14}{100}$	[New Line, Chilson
Pittsfield.....Aug. 9 to Oct. 31	5935	33534	5.65	63	94.20	532.2	44.57	133.16	752.36	6359.48	$18\frac{56}{100}$	Clay.
Clare .....Nov. 14 to Nov. 30	1753	.....	.....	....	.....	.....	.....	.....	.....	.....	.....	.....
	18058	.....								$16307.17		
SHOVEL NO. 3.												
Byron ..... May 2 to June 10	1609	6000	3.72	30	53.63	200.00	11.10	144.95	540.55	$ 2754.28	$45\frac{9}{10}$	Wet Clay in Ditch.
Vernon.....June 11 to Aug 4	3341	19811	5.92	45	74.24	440.20	19.60	170.45	1010.76	4439.89	$22\frac{4}{10}$	Hard Pan and Clay
Corunna.....Aug. 6 to Sept. 27	3787	25322	6.68	46	82.32	550.40	24.60	153.98	1029.34	5157.11	$20\frac{3}{10}$	" " " "
Monroe Junc..Oct. 1 to Oct. 16	407	4170	10.25	11	37.00	379.00	3.35	121.49	1244.75	654.08	$15\frac{6}{10}$	Sand.
Temperance .Oct. 15 to Nov. 12	1438	12984	9.02	26	55.30	499.38	9.10	158.02	1426.81	1859.66	$14\frac{3}{10}$	Sand.
	10582	68287								$14865.02		
SHOVEL NO. 4.												
Elsie Gravel Pit....July .. to Nov. ..	7122	62480	8.77	98	72.67	637.55	53.42	133.32	1169.59	$13356.80	$21\frac{3}{10}$	Long Haul.

The President.—This paper of Mr. Rigg's is before you for discussion.

Q. How are these iron pipes constructed?

A. We use for culverts rejected water pipe.

Q. But for these used on the trestles?

A. The iron cylinders; they are largely cylinder pipes.

Q. Are they driven?

A. No. In the case at Dundee they are founded on solid rock. At Ann Arbor we drove piles and the cylinder was sunk into the gravel 2½ feet and filled inside with concrete. The piles are driven inside of the cylinder and allowed to project into the cylinder part of the way and the balance of the cylinder filled with concrete. We used at Ann Arbor and Dundee a cylinder resting on solid rock.

Mr. Sears.—Do you use wrought iron cylinders instead of cast iron or water pipes?

A. No sir. We never used the wrought iron, although we are considering it now.

Q. Do you take any means of protecting your pipe?

A. They were all covered with carbon paint.

Q. How did you protect the end?

A. For the most part they are unprotected as yet, but eventually we will build a wall.

Mr. Sears.—What is the average cost per yard for moving the material and the average load?

A. The average cost per yard for the entire time will be, I should think, about 14 cents. The figures show cost of labor and fuel and supplies of all sorts, but make no allowance for rental of plant.

Q. How about the hauling?

A. The average haul was 2½ to 3 miles. On one piece of work we hauled as high as 20 miles, and very little was hauled less than ½ mile. The average haul would be fully 3 miles.

The President.—Mr. Riggs, how much cheaper do you think the work could have been constructed per yard, had you had the advantage of a double track railroad, instead of working on a single track?

A. Well, I think that the cost would have been very much reduced. It is pretty hard to say what per cent., but the greater portion of our delays were caused by the interference of regular trains on the road. On the south end of the road, particularly south of Dundee, where we have the trains of our own road and those of the C. J. & M., we have had about 50 trains per day and the delay was considerable. We had one or two instances in this district where we did not avearge over 3½ hours work out of a 10 hour day.

Mr. Sears.—Will you be kind enough to describe the concrete work on the piers?

A. We put in piers at two points, using concrete composed of 3 parts of Milwaukee cement—composed of 2, 3 and 5, using broken stone that would pass through a 2 inch sieve. The body of the pier or abutment where the concrete was put into a mold, using on the outside the rich Portland cement concrete for facing, and using sandstone coping; we have used the Berea and also the Hocking Valley stone. The piers of both places were very low, being only a matter of 1 foot to 1½ feet from the natural surface of the ground to the bottom of the coping. They were small piers.

Mr. Sears.—What was the cost of that pier compared with first class masonry?

A. About one-half.

Q. What was that one-half?

A. The cost of the four abutments was in the neighborhood of $835.00.

Q. I mean per cubic yard.

A. That was about $5.50. There is no stone at all on the line of our road, and the authorities have been rather opposed to the introduction of the use of masonry, and concrete is an opening wedge to what I hope will be something better.

Q. I thought there was a quarry at a point near Dundee?

The President.—It is a very poor quality of limestone and would hardly be suitable for railroad work. We examined it and did not consider it suitable for first class work.

Mr. Granville.—I want to hear Mr. Riggs on that point, particularly the construction of the concrete in these abut-

ments, or the use, rather, of concrete on that particular kind of work. Now, I am something of an enthusiast in the use of concrete, and believe that concrete properly put in is as good as first-class masonry and will weather just as well, and I want to bring out some of these points. Now, Mr. Riggs, of course, has not had the experience with the particular work that was put in there—it has not been in there long enough for him to tell how long it will last. I have no doubt about that, however; the concrete is not a new article by any means, but it has not been justly appreciated by engineers. It is becoming better appreciated each year and is coming into more general use than ever before. I picked up some time last year an article written by the engineer, I think, of the Knoxville, Cumberland Gap & Louisville Railroad, describing the construction of a piece of concrete work at Lonesome Valley crossing, on their road. At that crossing, some 800 to 900 feet long and about 130 feet high, they had an old wooden structure that collapsed under a heavy freight train and necessitated abandoning that particular crossing. They made a temporary shift by running down on one side of the valley and coming up on the other, using that for a considerable length of time. They finally got ready to put in a permanent structure. It was found that there was no native stone within reasonable distance that could be used; they then concluded to use a concrete construction. The construction of the superstructure was girders on steel piers. These on heavy concrete pedestals and at each end to be a concrete abutment some 28 to 30 feet high, and upon these abutments was the bridge.

I think this article was written some 12 or 18 months after the work had been put in, so they had some experience as to its durability, but the most interesting part was the discussion brought out by the paper as to the use of concrete by them in different parts of the country and in different structures exposed to the air.

Mr. Riggs.—I will state that the use of concrete for foundations for railroad structures is by no means new. It has been used to a large extent by the engineers of the Northern Pacific and of the Great Northern. Mr. J. W. Hendrie, now

General Manager of the Northern Pacific, and Engineer of the Great Northern are cranks on the subject of the use of concrete. Mr. Hendrie has used it in arches, in piers and in abutments, and in fact in almost all classes of work where first-class masonry could be used, and he tells me, with good results.

Mr. Hendrie, in some correspondence which I had with him, about the time we built the Ann Arbor bridge, relative to the use of concrete in steel cylinder piers, recommended this class of construction very highly, but with the proviso which I think is proper, that unless the construction can be anchored in the solid rock, that piling must be used, or some other means, to prevent erosion. I believe that concrete is going to take a very large place in foundation construction, particularly in a country like some parts of Michigan where no stone that is at all suitable, is available.

Mr. Sears.—I should like to hear a word from Mr. Gates on this topic.

Mr. Gates.—With reference to economy, the question I would like to ask is, what kind of cement do you use for concrete,—whether you use natural American cements or Portland cement? I have been in the habit of using natural cement for concrete which is not subject to frosts. If the concrete is laid during frosty weather, where the concrete will freeze at night and thaw in the morning, the use of natural cements would, no doubt, be poor practice. It would be necessary to use Portland cement only. I have recently,—within a week or two,—had a little experience on a cylinder pier, in which the specification was to fill the cylinder pier with concrete that shall have piles driven into the cylinder. When this recent high water came on, we had a rise of 19 feet at one point and the cylinder pier was floating at the time it was to be concreted. We had to guy it up to the side of the concrete platform; however, as contractors, we had no control over the matter, for it had to be erected by a certain time, and the contract was let for the bridge so late in the season, that it was necessary to use all the time we had, and we worked, rain, shine or freeze, and in this particular cylinder pier the coping

stones are being set now, but I do not anticipate any very good results from it.

Mr. Riggs.—Don't you think that when that class of construction is founded on solid rock, that it makes a very good substitute for masonry?

A. If your rock surface is level, and if you get support below the surface, it would be all right. We excavated 9 feet from the surface of the ground to the level of the rock; leveled off the rock and used 1¼ inch anchor bolts, putting in three bolts to each cylinder, anchoring through the rock, so that our cylinders were there practically 9 feet below the surface and rested direct on the rock. The diameter of these cylinders was 8 feet, so that there is not much question as to their stability.

Mr. Granville.—I have known of these cylinders being founded on the rock where it is of uneven surface, and instead of smoothing off the surface to an area greater than that covered by the cylinder, the location of the cylinder was found and then a groove cut to take the cylinder plates; that groove was cut in as deep as necessary, so that when the cylinder was set in there it was leveled up. There is no chance for the cylinder, so far as I can see, to move on that rock except by means of a thrust sideways. If you get your cylinder in a pocket in the rock there is no great chance of the cylinder being moved.

Mr. Riggs.—These piers at Dundee will probably form a pretty good test of that class of construction. The stream has a great rise and fall. The high water mark at our bridge is 17 feet above the ordinary stage of water, and it is a stream that is subject to a number of ice jams. We have had five or six about one mile above our bridge, so the probability is that this class of construction will have a very thorough test there.

Mr. Granville.—Using concreted cylinders for piers is not a new construction. There seems to be a great deal of doubt in the minds of engineers as to the desirability of using that class of construction, however. I noticed, particularly, two bridges crossing the Mississippi at Clinton, Ia., two years ago. One is a highway and the other a railroad bridge crossing

close together; in fact, one crosses the other at the south approach to the river, or nearly so, and I think both of these approaches to the bridge from the river piers, are constructed of large steel cylinders carried down into the mud, I don't know to what depth, but there are piles driven inside and filled with concrete. Where there is danger from the floating ice or logs or other debris, bracing is used between to prevent anything of that nature getting in there and wrecking the cylinder, that is a solid web. Instead of using struts and diagonals, a solid web is used in between.

Mr. Gates.—The great difficulty, it seems to me, in cylinder piers, is to get the diameter of the cylinder pier large enough to have the proper bearing surface inside of it for the load of the bridge and the weight of the material inside of it upon the foundation below; whether this be piles or something else, or solid rock, it don't make any difference

Mr. Riggs.—Don't you think that the reduction of the diameter, which we used at Dundee on the plan which you submitted in your bid on that work,—don't you think that some scheme of that sort, where the larger diameter is at the bottom and reduces toward the top, would solve that?

Mr. Gates.—Yes, sir Of course you can hardly ever, in a clay bank, drive more than 6 or 7 piles inside of the cylinder pier, and those 5 or 6 piles will have to take all the weight.

Mr. Sears.—It seems to me that one of the principal objections is that you would want a retaining wall at the end of your bridge, and you could not get it. By the shore you want a retaining wall, and you could not make it with the cylinder.

Mr. Riggs.—At Dundee we have quite a long trestle on the north and a trestle bridge from the south. We have five to six hundred feet of trestle in addition to our span, and it would be impossible to shorten that.

Mr. Douglas.—How much cheaper are cylinder piers than solid masonry piers?

A. The piers at Dundee,—the entire work of building,—cost us about $2,450.00, while the estimated cost of masonry was $3,700.00.

Q. What would it have cost, Mr. Riggs, had these piers been put in with concrete with a heavy stone coping?

A. A very little more than the form of construction used.

Mr. Sears.—I haven't any doubt about the use of concrete for bridges. I would not hesitate to make a large culvert completely of it. I think, if properly proportioned, it would stand in this climate. There is no question at all but that it is cheaper than any stone you can use, and you can make large pieces cheaper than you can quarry it.

The President.—Are we through with the discussion of this paper?

Mr. Ames.—I was saying to Mr. Douglas that I built, a year ago last summer, some sidewalks of Louisville cement as an experiment, and about half of the blocks I made are in good condition to-day. The other half, the top is cracked and scaling off. The lower part seems to be in good condition.

Mr. Granville.—Right in the same line of experience, two years ago,—in 1894, rather,—I had a notice from the city authorities to renew my sidewalk, and I put in a concrete walk. At this time I was doing a little concrete work here in the city, putting in some curbing on one of our main streets, and I took the force that I had there, at the time when I was stopped from work, and went and put in this concrete sidewalk with the force. I experimented a little on it in this way.

The walks usually put down in this city are made entirely of Portland cement. The bottom of a poorer quality than the top dressing. I got some Milwaukee cement, which cost me 75 cents per barrel, and put the bottom 5 inches, and on that another made in proportion of about 1, 2 and 5; 2 of sand and 5 of gravel. The top inch was put in of Portland cement, made in proportion of 1 to 1, and the sidewalk is in very good condition to-day. It has not shown a crack and has given perfect satisfaction, except in the case of one or two blocks, and my opinion is that the work at that point was not properly done. The surface is all right. It is not cracked, nor does it show any signs of giving out, and this is its second winter, but in walking over it, it gives forth a hollow sound. There are perhaps 5 or 6, or perhaps more, blocks in the whole length of

that sidewalk, 100 feet in length, that shows a hollowness. The reason for that is this: The foreman who had charge of the work got in too much of that bottom, and allowed it to become dry, or nearly so, before putting the top coating on, and consequently there was not a proper adhesion between the upper and lower coats. The cost of that to me, (and my labor was more expensive than it ought to have been), the whole thing cost me about 8 cents a square foot, and you can not get a very good job done, using Portland cement, for less than 12 to 14 cents. You can let a contract at 12 to 14 cents for Portland cement walk, 5 inches thick, but I defy you to get a piece of work done that will give good results at that price. I used Milwaukee cement to see how cheap it could be done with good results.

THE MECHANICS OF A CREAM SEPARATOR.

H. K. VEDDER.

The problem here presented may be considered one in agricultural engineering. It is well known that the modern method of cream separation in butter-making requires that the cream be taken from the milk immediately after milking. This is accomplished by some application of the so-called "centrifugal" action, a purely mechanical process; and machines for the purpose are called cream separators.

Such a machine consists essentially of some form of vessel or bowl, capable of rotation at high speed about an axis, with suitable devices for receiving milk into the bowl and for conducting from the bowl streams of the separated cream and the "skim-milk." To permit the high speed of rotation that seems to be necessary, not only must the construction of all parts be very perfect and their adjustment delicate, but the rotating parts must be carefully designed to avoid rupture while in motion.

Separators of many forms are used in the dairy department of the Michigan Agricultural College. Among those in operation there during the year of 1894 was one for which was claimed, by its manufacturers, marked superiority over others, in the matters of cheapness, lightness, ease of running, etc.; much of the claim being based on the fact that the metal used in the construction of the machine was very light, being very nearly pure aluminum. The actual composition of the metal was said to be 95 per cent. aluminum with 5 per cent. of iron. While the machine was under trial at the college, a report came that one of the same kind had burst while being operated for exhibition purposes at a county fair. The college dairy experimenters conceived a distrust of the separator, which led to the analysis and tests recorded below.

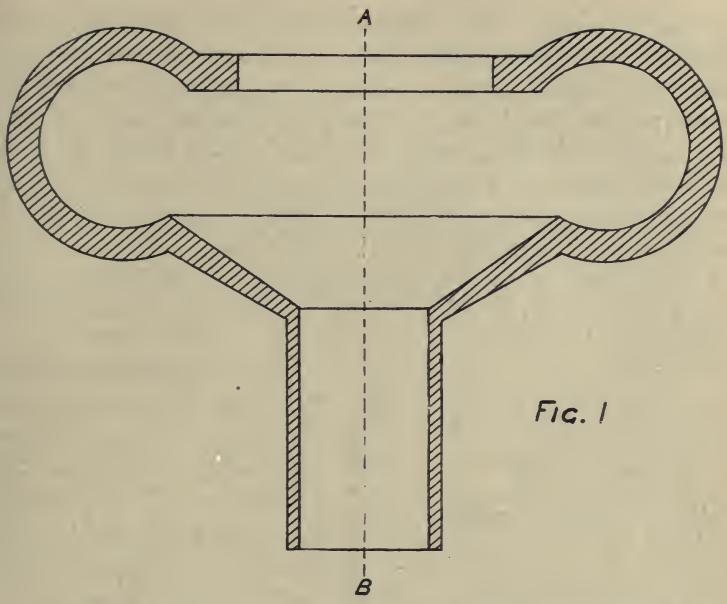


FIG. 1

The form of bowl used in the separator is shown to scale in Fig. 1, which represents a vertical section of it, except that in the casting the sharp edges are rounded off. It is symmetrical with respect to a vertical axis AB, about which rotation occurs. This bowl was designed to attain and maintain a speed of from 6,000 to 8,000 revolutions per minute, in practical operation. The higher number will be used in the analysis.

We shall first attempt to determine the stress on the metal of the bowl, induced by the given speed of rotation. The problem is very similar to that of determining the stress in a revolving flywheel rim or a grindstone. From mechanics we know that if a body rotates with a uniform velocity about an axis, lying in a plane of symmetry, there is induced a force away from the axis $= w^2 M p$, in which w = the constant angular velocity of rotation, M = the mass of the body and p = the distance of the center of gravity of the body from the axis. If we were to take as the body under consideration the half of the separator bowl which lies on one side of a vertical plane

through the axis, this formula would give us the total force exerted on or by the other half, i. e., the stress in the vertical section. But the stress in such a section is not uniform over the whole section, being evidently greatest at those points of the section farthest from the axis. So it would seem that we would arrive at more satisfactory results if we would deal only with that portion of the bowl which may be conceived as generated by a portion of a circular ring, shown in Fig. 2. Over any vertical section of this portion of the bowl we may, without great error, consider the stress to be uniformly distributed.

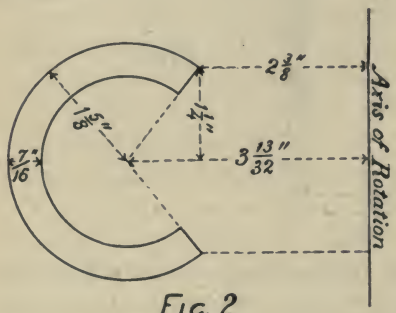


FIG. 2

The dimensions given in Fig. 2 are from actual measurements. Combining these dimensions in obvious ways, we find the volume of metal in the portion of bowl generated by the ring to be 70.4 cubic inches; whence, is obtained the weight=7.27 lbs., and the weight of the half bowl=3.64 lbs., the weight of the metal being 178.4 lbs. per cubic foot. Then for substitution in the formula given above, using the foot, pound and second as units,

$$M=\frac{\text{wt. of half bowl}}{\text{acceleration of gravity}}=\frac{3.64}{32.3} \text{ mass units.}$$

$$w=\left(\frac{8000}{60}\times 2\times\frac{22}{7}\right) \text{ radians per second.}$$

$$p=(\text{something between 2.17 in. and 3.2 in., say 2.5 in.})=\frac{2.5}{12} \text{ ft.}$$

(The determination of the limits between which p lies, consists in considering all the metal of the half bowl to be (a) concentrated in a semi-circular wire of radius$=3\frac{26}{64}$ in. and (b) in one of radius=5 in.; and thence deriving the limits as given above.)

Therefore, the tension to be resisted being denoted by T,

$$T=w^2Mp=\left(\frac{8000}{60}\times 2\times\frac{22}{7}\right)^2\times\frac{3.64}{32.2}\times\frac{2.5}{12}=16503 \text{ lbs.}$$

But this is due to the revolution of the empty bowl. An additional stress will be induced by the revolution of the contained milk. When the separator is filled with milk, a volume of the liquid weighing 4 pounds may be considered as affecting the required tension, and a computation similar to that above places the amount to be added at 5,252 pounds. Hence, the total tension under working conditions is 16503+ 5252=21755 lbs. to be borne by 5.6 square inches of section. This gives a stress of about 3,900 pounds per square inch.

This stress would not seem to be excessive, to one who has become filled with popular notions as to the strength and utility of the metal aluminum, and it must be confessed that at the time of making the analysis the writer felt that the stress found was within safe limits. But, to complete the examination, standard test pieces of the metal used were obtained through the kindness of the manufacturer, and these were broken by tension in a Riehle testing machine at the college. The results were rather surprising. Sixteen pieces were broken, showing a variation in ultimate tensile resistance from 9,814 lbs. per square inch to 14,864 lbs. per square inch; and giving a mean value of 12,867 lbs. per square inch.

Comparing this ultimate resistance with the stress induced by ordinary working requirements of the separator, it is seen that there obtains a factor of safety of about 3, which would seem to be much too small for machinery of the kind in question.

It may be added, in conclusion, that since this paper was written, I have been informed that the manufacture of the separator with this particular form of bowl has been discontinued.

Prof. Vedder.—I have brought along several of the broken pieces, and anyone who is at all interested in the metal aluminum, can find them on the table over here, with a card attached, giving the peculiar behavior of the specimen under stress. I wish here to speak my thanks to Prof. Pashby, of the Agricultural College, who made the tests for me.

The President.—This paper is before you for discussion, gentlemen.

Mr. Sears.—I did not understand where that failed; that machine.

Prof. Vedder.—On just such a section, a diameter section. The one that burst went through the roof at Hornellsville, at a county fair.

Mr. Hubbell.—Had the machine been built of steel, with the well known strength of steel, as against the lightness of this aluminum,—would the lightness have the advantage?

Prof. Vedder.—I have not gone through the computation. I imagine the aluminum must have the advantage over the steel. I think the increased weight of the steel will more than overcome the advantage resulting from its strength. I think the manufacturer of this bowl has moved to Lansing within the last few days, and intends to make another form of bowl there. I think he is going to use the same material with a much smaller bowl.

Mr. Sears.—It is a good plan to leave the farm house where he goes to work.

Prof. Vedder.—The one at the College got refractory and nearly killed the head of the Agricultural Department. One of the bearings became over heated. It was not evenly placed. With a machine able to rotate at such a high speed, a little lack of centering means a strain on the bearings.

The President.—The subject of aluminum is brand new to me. I have known of its existence, but I have not investigated the subject, and I would like to know if anyone does know to what extent aluminum is being employed in machinery. So far as my observation goes, aluminum, so far, has been most largely used in making household utensils and ornaments.

Mr. Hodgman.—Isn't it principally used now as an alloy for other metals?

Mr. Wells.—I couldn't say. I took considerable interest in examining the exhibit of Gurley Bros. at the fair, and I visited their works at Troy this last year, and they told me that in the manufacture of levels and transits, they have found that the metal is deficient for bearing surfaces. They have made some levels, which they say have met with a good deal of suc-

cess, but in all the bearings they have introduced brass or bell metal.

Prof. Vedder.—Anyone who cares to go into the use of aluminum will find it treated in Mr. Kent's Mechanical Engineers' Pocketbook. I find there that the stress per square inch, as ascertained from a large number of tests, is put down at 15,000 pounds per square inch for castings. Before reading that, I had supposed that the ultimate resistance was considerably higher. Rogers, in his book on aluminum, says that it has an ultimate strength of 26,800 pounds.

Mr. Wells.—When the prices of aluminum were cheapened,—about the time aluminum was worth $1.50 a pound,—a statement was made somewhere that aluminum possessed about the same tensile strength as steel, but everything I have seen since then, has tended to lower that estimate.

Prof. Vedder.—I don't mean to say that I have been laboring under that delusion for some time past.

Mr. Wells.—I have been distrusting that statement, which I heard some years ago, and I was entirely at sea as to what was a safe tensile strength of aluminum; 26,800 pounds, you say, on one authority?

Prof. Vedder.—Yes,—that is, of course, a later work. 12,876 is another estimate.

Mr. Pashby.—Taking equal weights, I think aluminum would have about the same tensile strength as boiler steel.

Mr. Wells.—I have heard that by using a small quantity of aluminum with steel, the tensile strength of the steel was increased.

Mr. Hodgman.—I think I read in the Engineering News, some time since, that it can be employed up to about 5 per cent. to advantage, but I have not pursued the subject. Can anyone help us out on that point?

Prof. Vedder.—I am not sure, but I think that a small quantity is used sometimes for the purpose of making pig nuggets. It seems to drive out the impurities, air, etc.

Mr. Hodgman.—I have read statements within the past year or two, to the effect that aluminum is now principally used for an alloy with other metals, but in small quantities, to

improve their casting qualities and strength. On the other hand, aluminum alloyed with some other metals seems to possess high tensile strength and other requirements for mechanical purposes.

Mr. Pashby.—The limits are between 2 and 15 per cent. Never less than 2 or more than 15 per cent.

Remark. Aluminum is being introduced in the manufacture of bicycles to lighten up some parts, though I do not know with how great success. I know that one bicycle firm has recently purchased a considerable amount of aluminum for parts where strength is not particularly the point desired, and at the same time it tends to lighten the machine.

The Pittsburg Reduction Company has recently located its plant at Niagara Falls, to take advantage of cheap electricity in the manufacture of the metal.

Q. Do we understand from this paper, that all these separators are dangerous? Have there not been a great many throughout the country, which have been running successfully for years?

Prof. Vedder.—There is no question about it.

I had in mind bringing up a discussion on aluminum from another point of view. What should be the factor of safety, for machines to be operated at such a high rate of speed?

The President.—Can't Prof. Vedder tell us?

Prof. Vedder.—I have an opinion. I think we ought to have factors of about eight.

Mr. Sears.—I would make it ten, and then get out of the way.

Mr. June.—What was the power employed?

Prof. Vedder.—An electric motor.

Mr. June,—Was any test made with hand power?

Prof. Vedder.—I am not sure. I answered your question in that way because all the separators are run by electric power at the College. At times, for real practical purposes, they do operate them by hand. I don't know whether they can get up to that speed of rotation in that way. I believe they must attain the minimum,—something like 6,000 revolutions,—

in this particular machine in order to get a clean separation of the cream from the milk.

Mr. June.—I know they are making hand machines, and in many cases, of course, they must be used in order to meet the practical needs of the creamery methods.

Prof. Vedder.—I think that makes no difference in the required speed of rotation. The machines must be so constructed as to bring up the speed of the bowl to the same point.

Mr. June.—But that is not the question. The idea is whether they don't do it by hand?

Prof. Vedder.—I fear they go beyond it by electric power, and that is one reason why our factor of safety should be so high. It is next to impossible to count the revolutions of a machine rotating at so high a speed.

Mr. Sears.—There seems to be no uniformity in the strength of this metal.

Prof. Vedder.—It is very erratic. We have there, one specimen broken in two places—the first fracture covering a larger area than the second—the tensile strength derived from the first smaller than from the second.

Q. What is the lowest?

A. I gave the minimum of 9,114 pounds per square inch.

Mr. Rogers.—Are other makes of machines in the habit of upheaving like this one? There are, I suppose, a number in use?

Prof. Vedder.—I suppose it is a pretty small percentage of the whole number that has ever blown up.

Mr. Hodgman.—We have two of those separators near where I live, but they are both run by hand.

Mr. Sears.—You better move.

Mr. Skeels.—He wants to build a storage reservoir.

Mr. Pashby.—As to the question of running these by hand. That is done at the present time in the dairy department. The power required is only a small fraction of a horse power, and a man can turn a crank quite handily for an hour, the time required for separating about 200 pounds of milk. That is with a comfortably, easily running motion.

Mr. Hodgman.—A friend of mine, Mr. Brown, editor of the Michigan Farmer, runs a separator at his house, near where I live, and he says it is no harder to run than a fanning mill.

Mr. Pashby—A point that has not been brought out in this, is the extension that the metal underwent during the test. I didn't have any extension meter to put on, and I can only give a rough approximation, but in scaling the piece, I find an extension of about 1 7-10 per cent. in seven inches, and also a reduction of about 8 per cent. in the area of the cross section, at the point of fracture.

Q. Mr. Pashby, you conducted those tests with these pieces that are here; could you favor us with a little lecture on your experience in making these experiments?

Mr. Pashby.—I don't know that I could say anything that has not already been brought out.

The form of test pieces that I designed for this work is as represented here (indicating). Then, as a variation, I had the outside skin taken off from two or three specimens, and I can say that the metal is very difficult to work in the lathe. It is very much like rubber; it is very hard to turn and frills up in an unsatisfactory manner.

The testing machine is one that is worked by hand power. I suppose the results are not quite so accurate as might be obtained by the use of machinery—that is a power machine.

I would say that this extension was measured by taking dividers and spacing them about seven inches here, and that I had to put on a weight of about 3,000 pounds on this piece and there was an extension of about 12-100 of an inch, amounting to 1.7 per cent. in that length of seven inches.

The President.—Did it regain its original position after releasing that power?

A. Yes, I removed the load at 2,000 pounds and it went back very nearly to its original length. I could not be exact about that.

The breaking load on this piece was 3,850. It was on that section, and that amounted to 14,092 pounds per square inch.

Q. Did you establish the elastic limit in this test?

A. No, I did not. This piece that broke here in six places I should attribute to its being put into the jaws of the testing machine improperly. There must have been a twist on it, so that it tore, like a piece of paper.

Q. I should not think you could take the results then, if you did not get it into the machine well?

A. I computed this separately from the others. This section here (indicating) is the one that gave me 9,814 pounds to the square inch. That section broke at 8,000 pounds, and this at 8,405 pounds.

Mr. June.—These pieces are castings?

A. Yes.

Q. Are they capable of annealing?

A. I think not.

The President.—Mr. Sears asks the question as to how this behaves under compression?

A. I don't know. I should think, though, that it would not compress very well, because it bends easily.

Mr. June.—What results are obtained by working this, and do the same conditions exist between cast and wrought aluminum, as between cast and wrought iron?

A. I could not say.

The President.—I think that would be a first rate paper for some one to give us next year. We seem to have more questions than knowledge on this subject.

A BASKET OF CHIPS.

MR. SKEELS.

One industry of the engineer and surveyor is platting additions to cities and villages, and making a map thereof. We are compelled by law to submit said map to the auditor-general of this state for his approval. This is humiliating. While honesty and integrity stimulate him in the discharge of all official duties, his lack of proper knowledge disqualifies him to pass judgment. Justly, we should not censure him; this duty has been attached to his office, unaccompanied with the qualification necessary for the proper discharge of such duty. Any effort that would result in amending this act; would be a move in the interest of right and justice. A commission of members of this association can formulate a plan—make specifications— that would rid us of this humbug.

At the annual meeting of your board of directors, the question of advancing members of this, our, association to the exalted position of honorary members, was informally in discussion. Is not constant, earnest work for the advancement of the best interests of this association, regardless of age or infirmities, the best record for such advancement?

In January, 1899, occurs the twentieth anniversary of the organization of this society. It seems to me this would be a most fitting time for a royal banquet, commencing now with small contributions to a sinking fund from each member, to be kept up annually, thereby securing a sufficient fund for the committee to prepare a feast that would tickle alike both palate and intellect.

Do the members fully appreciate the genuine worth, the intrinsic value of "The Michigan Engineers' Annual?" Do they know that some of the papers read at these meetings and published in its annual are the best, are authority on the subject which they have under discussion? The authors are

practical men. Each one's paper is a digest of that matter up to date. Already progressive societies are asking for the annual to place on their tables. Our best attorneys read it, and ask the engineer on the witness stand, "Are you a member of the Michigan Engineering Society?" I fear that many of us do not realize that it is a hand to hand conflict with the secretary to get the annual out on time. If each one would assist this worthy officer in this by getting an advertisement from somone in his locality, and each member would insert his card, a nice sum would be the result.

Do we realize the usefulness, the far-reaching influence and practical worth of the Michigan Engineering Society? What it has actually done for the public good should be not the measure but the foundation of its coming service. And do these young men, enrolled among its most worthy members, fully realize that soon they must take the helm and guide this ever-growing organization on to more beneficial, more practical usefulness? The ones that have brought it to its present standing must pass on. Time will come when, though every joint and bearing of the machine be cleaned and oiled, it will not keep in proper adjustment—will cease to work. Some of us older ones have done much land surveying—even before that county surveyor had adjusted the work of the government surveyor—and often in projecting a line we came to a seemingly impassable swamp, the accumulation of ages. We pass on into it, setting stakes or pickets at intervals in line. Each time we move our instrument we look for some way to go around and shun the rough looking path; but when we got through a feeling of satisfaction would come to us as we looked back over the work and saw our pickets standing in regular alignment. So, my friends, at the final passing, may we look back on a life with pleasure, and the same satisfaction, and see some monuments standing in perfect alignment.

The President.—Kate Field says, "You want to reiterate reiteration," and I was glad to have Mr. Skeels bring out that point of assisting the secretary in obtaining this advertising.

Mr. Granville.—One point mentioned in Mr. Skeels' basket I thought was a good suggestion, and I hope means

will be taken by which it can be followed out, that is a banquet three years hence. I think it would be a very good plan to start and create a "sinking" fund, and a little applied during each of the coming three years, would not be missed and, in the aggregate, would amount to considerable and enable us to do the thing up in good shape. I think that suggestion ought to be carried out.

Mr. Walker.—That banquet is two or three years off. It don't seem to me that it is necessary to worry about that. It seems to me it is only necessary to appoint a meeting at Saginaw.

Mr. Skeels.—My idea of that, was to begin now and to have small sums contributed, for instance, if each member feels so disposed, say 25 cents a year, and by that time, 1899, we would have sufficient. My idea of a banquet was not a spree or a hurrah, but to get some of the best talent we can, and have them advised of it long enough before so they can prepare themselves properly, and have a good, substantial meal at the proper time, and have the evening spent in what might be called an intellectual feast,—perhaps interspersed with something lighter; that was the object I had in view in writing that. By commencing now, we can get ourselves thoroughly prepared. It is not necessary that each member shall contribute, but if it is agreeable to all to do so, I think we can have a meeting that would be very beneficial.

Mr. Hodgman.—I believe very much as our friend, Mr. Skeels, does in regard to celebrating our twentieth anniversary. I think it is a good time and I feel as he does as to the matter of holding the banquet. That would be an incidental affair. I am a great believer in mixing up with our annual meetings a little matter of lighter vein. I think it comes in as the dessert does with our regular meals.

I have felt that perhaps in the attempt we have made twice, to have these social meetings, perhaps the members had an idea it was meant solely to be funny. Now, it strikes me that the best part of the fun is if you don't have too much of it. You must have it mingled with something of a different

character. If you want to have the best effect of a real funny story, it must come in contrast with something that is not so funny.

If we could have a regular prepared program with someone for a toastmaster who had the right faculty for bringing out the members, and have a program of addresses, some light and gay and funny, and others that are not funny, I hope we can have it.

The President.—Mr. Appleton, let us hear from you on this.

Mr. Appleton.—Well, I have been cogitating. Pretty big word for me. I have been thinking, Mr. Chairman, that that was not a very big basket, but Skeels used to be a good chopper and he hasn't forgotten how. They say a good chopper cuts big chips, and three or four of those chips fill that little basket.

All of these suggestions seem to be all right. This is the seventeenth anniversary of the society; there are three years before the twentieth. I do not know but our friend, President Lincoln's, idea was a good one, "to get to the river before you cross it." We have nearly one-seventh of the time to cross over before we get to the twentieth. May we all pass over and reach it. Now, I think it would be an excellent plan, while it is perhaps a little bit too early, to start in with this thing.

Mr. Hodgman.—It strikes me that the proposition is not to go at it and to get up an entertainment now, and arrange all the details, but to consider the propriety as to whether we shall do something of that kind at that time. If we know we have a river to cross, we will be ready to cross it when we get there.

Mr. Appleton.—The object is to build a bridge and have it ready when we get there. This chip on that subject, I understand, is to erect a bridge so that we can march across *veni, vidi, vici*, in fact as Julius Cæsar did.

Mr. Granville.—Then I will put it in that shape, although I thought it would come better from Mr. Skeels; but I will make a motion that the secretary be requested to let the members of the association know that this has been contemplated, and stating that any donations offered would be received and applied to that purpose.

Motion supported and carried.

HISTORICAL NOTES.

L. G. STUART.

If any other person than Mr. Dorr Skeels had asked me to write a paper for the Michigan Engineers' Association I would have declined with thanks. But Mr. Skeels is a friend of mine,—at least I always considered him such,—and in deference to his wishes I have consented to prepare something for your learned society. My paper, let me be understood at the very beginning, is not for your instruction, for what I do not know about surveying would make a fair sized library. When it is said that a politician has gone off on a tangent, I know what is meant, but when a surveyor talks of tangents I confess myself up a stump, and the plumb always suggests to me something that grows on trees. I will not endeavor to instruct this learned body, for by so doing I would make myself ridiculous and cover my friend, Mr. Skeels, with confusion, but it is possible I may entertain you for a few minutes and it is with that purpose in view that I write this paper.

I have in my possession an old document, printed in Washington, to accompany a bill in the House of Representatives. It is dated March 6, 1838, and will doubtless be found in the house documents of that year. But as all of you do not possess the annals of Congress and do not read them if you do have them, at least I do not the few that I have, I will take it for granted that some of you, at least, have never seen the document I refer to.

The bill which this particular document accompanied was one to increase the compensation of the assistant surveyors in Michigan. They had been receiving $3.00 a mile as the maximum and wanted $4.00. The increase was strongly recommended by Robert T. Lytle, then surveyor general, with headquarters in Cincinnati, and in urging the matter, among other things, he wrote:

"The tract of country now in progress of survey in Michigan (he means northern Michigan) presents greater obstacles to the surveyor than any portion of this surveying district. It is almost a trackless and interminable wilderness, covered with an unbroken forest, a large portion of which is tamarack, hemlock, pine, cedar, maple, etc., and abounding with burnt and fallen timber, thickets, swamps, marshes and ponds; all of which render the progress of the surveyor exceedingly difficult, laborious and tedious, and the conveyance of provisions by wagon or any other wheeled carriage impracticable. And the surveyors have frequently been obliged to leave their pack horses behind, and for several days in succession pack their provisions on their backs. To this may be added the high price of provisions at the frontier settlements, and the great difficulty of procuring their chainmen and other hands, and the high wages paid to them, together with the increased exposure of their health and lives in the most inclement season of the year."

He further says that it is difficult to engage experienced and skillful surveyors, and eloquently urges that the rates of compensation may be increased to a proper figure. He appends to his recommendations a few letters from the assistant surveyors, in which they describe the difficulties of their work. As this meeting is being held in Saginaw, as charming a city as will be found in all Michigan to-day, I will quote extracts from a couple of these letters written from this quarter. The first that I shall give you is from Lewis Clason, written from Mosquito Headquarters, August 13, 1837. He left Cincinnati on July 11, reached Detroit on the 25th and then, after an eight day voyage in a "little seven by nine sailboat," reached the mouth of Pine River, on Saginaw Bay, from which point he wrote. He vividly describes the difficulties he has encountered and overcome, or tried to overcome, of the depth of the water in the swamps and the scarcity of provisions, and then he continues:

"In addition to the swamps there is another annoyance, for the present, even less tolerable. I allude to the mosquitoes and gnats. They are more numerous and voracious than

I have ever met with elsewhere. I do not doubt but that their number is sufficient upon every quarter acre to consume the last drop of blood in my entire company. They swarm about us in a cloud, not to guide us through the wilderness, but to devour. But thanks to the season's changes, a few weeks at most and the early frosts of this latitude will give them their quietus."

But it is left to J. A. Rousseau to vividly describe the mosquito, and he does it under date of September 1, 1837, from the Saginaw Bay. He had been having a hard time of it finding his lines and following them, and not the least of his troubles was the fact that "the circumambient atmosphere was groaning under the burdensome load of countless millions of myriads of mosquitoes, whose bite was like the sting of so many bees. You can have no idea," he writes, "how troublesome the little, slender, soft-billed, weak-looking, long-legged gentry are; but when I tell you that they bite a man through his clothes in a thousand places at a time, and through a thick pair of leather gloves, you will, like me, think they are not so contemptible as you at first imagined."

With the possibility of making you weary, I will quote no more from the ancient document, but will refer to an early Michigan surveyor whose name stands high in the annals of his state. I refer to Lucius Lyon. He came to Michigan territory about 1821 from Vermont, and for many years worked as a surveyor. In 1833, when off in the woods, he was nominated as a delegate in congress from the territory. With little, if any, campaigning on his part, he was elected and served the term of two years. Michigan applied for admission to the union and in the constitutional convention of 1835 he was a delegate. The first legislature elected him, by a unanimous vote of both houses, as one of the first two senators from Michigan, and in drawing cuts to see whether he should hold the long or the short term he drew the short. The admission of the state entailed a long and weary contest which doubtless most of you are familiar with. Ohio wanted the Toledo strip of territory and got it, and in exchange for it, through Mr. Lyon's efforts, Michigan secured what is now our

upper peninsula. Mr. Lyon served four years in the senate and subsequently a term in congress from the western district, then the second district, of Michigan. At the close of his congressional term he was appointed surveyor general with headquarters in Detroit, and died in 1852. This, briefly sketched, is the career of one of Michigan's ablest men of the early period, and now I will give you a couple of extracts from letters written by him, found in the letter press books which he preserved and which still exist. One was written April 12, 1838, and relates to surveying, giving advice to a young friend who has just secured a contract:

"You want patience, industry and perseverance to go through with your contract," he writes. "You must consider that you will not be able to make any money of consequence unless you push ahead as fast as possible. You must be out as soon as you can see daylight in the morning and go as long as you can see daylight at night. There is nothing like energy and industry to help along in such business. The most rapid progress I ever made in surveying was in the winter, west and northwest of Fort Gratiot, in one of the worst timbered, swampy countries I ever saw. I subdivided those ten townships in twelve weeks, including the time spent in going out and returning to Detroit, averaging for the whole time a fraction over eight miles a day, including Sundays, which we did not stop to keep. But I never worked so hard in my life and believe I never shall again."

In June, 1843, writing to a personal friend, Mr. Lyon told of some of the public work he had done, and this letter, or a portion of it, may be of interest historically. "I spent ten years of my life in surveying public lands, Indian boundaries and state boundaries in Michigan and Wisconsin, and no surveys have ever been more faithfully or accurately made than those of mine," he wrote. "Every line was run by myself personally, and in running them I have walked in the woods more than 50,000 miles. The boundary between Illinois and Wisconsin is one of these lines and was established by me as commissioner on the part of the United States. The meridian running north from the surveys in Illinois and crossing the

Mississippi at Rock River Rapids, and re-crossing it again near the mouth of Fever River, and passing near the town of Galena and thence on to the Wisconsin River is another. Most of the mining country in Wisconsin was surveyed by me, as well as a large portion of the State of Michigan on the eastern side of the Lake."

Trusting that the meeting of the association may be pleasant and profitable and that Grand Rapids may have the pleasure of entertaining you next time, I am,

Very respectfully,

L. G. STUART.

QUESTIONS FOR THE MICHIGAN ENGINEERING SOCIETY.

Question proposed by Mr. Hubbell:

"How can the wood platform on top of piles, which constitute the foundation of a stone pier of a bridge be preserved? In the original construction, this wood work was under water, but now it is exposed to the atmosphere by reason of the water receding."

Mr. Sears.—Build a dam below and raise the water.

Mr. Skeels.—Saw it off, under the water, and let it down.

Mr. Hubbell.—I would like to ask without joking, if there is any way of covering that, that will protect it?

A. The best thing I know is wood ashes.

Mr. Holmes.—I would suggest treating it with a solution of silicate.

The President.—In the paper I am down for, I have some points upon that subject—I won't take up your time now.

Mr. Sears.—In 1867 I placed 68 piles under a draw span, —oak piles. They were cut in the winter and seasoned in the water, you might say. Driven and left about 3½ feet above the average low water.

I bored in each of them, and plugged them with salt, and they were covered with a platform of good timber. We cut them off two years ago and they were in pretty good shape, after 29 years.

Q. You bored and plugged them with salt?

A. Yes, sir. I don't know how much good the salt did, but they were in pretty good condition.

The President.—Salt is a good antiseptic. The decay in wood is caused by the fermentation in the sap; fermentation promotes the growth of germs, and if you introduce some antiseptic, these germs are killed and the wood consequently preserved. The only objection is that salt is so soluble that

upon exposure it washes out; that, also, is the objection to the other systems of preserving timber, which use soluble salts.

Mr. Leavenworth.—A man on the west side made the statement to me that he built a sidewalk some years ago, and at the same time his neighbor, whose property adjoined his, built one; he says that he filled his, after excavating between the stringers, with refuse salt from the salt works, and that that part which had the salt rotted out more quickly than his neighbor's, which did not have it.

Mr. Sears.—It wasn't good salt.

The President.—It would be a question of getting the salt into the timber, and unless you have a well seasoned timber, it cannot be done very well. If that timber was put in green, with the sap in, it is a question whether it would do any good. It might protect the outside and induce dry rot at the heart. If the timber is well seasoned, I should think that the docks mentioned, if a little head of water were kept on them for a time, it would force it down, but I can see that you have a very unfortunate condition of affairs.

Q. I would like to ask Mr. Hubbell if that is decayed now?

A. I have not examined it closely,—the extent of the evil only revealed itself to me recently, and I am studying it closely.

Q. Can't you put a casing around it and fill it with concrete?

A. There is fourteen feet of water at this point. The water in the river was sixteen feet deep at the time we built the bridge, and we sawed the piles off thirty inches below the surface of the water and put a platform on, like this table. It is 26 feet square and there are 100 piles. After driving the piles, I put in all the sand I could drop in among them. The stone pier, which was 22 feet in diameter, is put on top of this platform, which is a foot thick. Of course the river has been dredged, which partially accounts for the lowering of the water, and the whole water of the lake has lowered somewhat, so that the water has receded three feet.

The difficulty is to get this dry or else to keep it wet; the boats passing back and forth wash the water up, even to the

top of the platform frequently, and there is a difference in the rise and fall of the water.

I had thought of the salt remedy and I had thought of taking something of the nature of matched flooring and letting it extend down two or three feet in the water, and one or two feet above the platform, thus forming a rim around the platform. The siding would have a tendency to keep a free circulation of air, and then putting twenty or thirty barrels of salt around. I would willingly use up fifty barrels a year, if it would do any good, but I am not sure about that salt penetrating and reaching the foot of the piles. It is eleven feet to the central portion of this.

Mr. Wells.—I have serious doubts of its getting in there if the timber was not seasoned.

A. No, it was green timber.

Q. How about the practicability of filling in there with cement?

Mr. Hubbell.—I had thought of an iron or wood casing, but it would be quite expensive.

Q. Couldn't you cut them off?

Mr. Hubbell.—How would you get in there, twelve feet? It is on Manistee River, a swing bridge.

Q. And in the receding of the waters, you have been left high and dry. I should think the idea which has been suggested of putting in some form there, so you could build your concrete over that, would be about the only way in which you could have any great success.

Mr. Sears.—Did you put a curb around to hold the stones?

Mr. Hubbell.—Why, I put in what stones I could, filling them clear to the top in the sand, but there are few stones on the outer edge.

Mr. Rogers.—We have a similar condition on two of our City bridges and I thought seriously last spring of putting boxing around these and putting concrete over the grillage and giving it sufficient slope so that the water would run off, and I was afraid rot might set in, under the concrete.

Mr. Wells.—If you excluded it thoroughly from the air, you wouldn't have any rot, in my judgment.

Mr. Hodgman.—There is a gentleman present who has had some experience in this line, Mr. Hunt.

Mr. Hunt.—My experience would not do any good in that case. I think after they were well cemented in, the piles would be all right. If I had that bridge to contend with, I think I should put the cement in, from the bottom up.

Mr. Rogers.—We have underneath this grillage, a rip rap, and the piles are not exposed. It is simply a part of the grillage. Most of the time it is above water.

Q. Are those oak piles?

A. Yes, sir. It is not the piles we are thinking about, as much as the timber on top of the piles. I was not worrying about the piles, because they are still wet.

Remark. I have two feet of space that I have sheet piled.

Mr. Wells.—I should think that you would sheet pile that. You have a lot of stone in the bottom now. I should think if you would crowd that pretty thoroughly as far as it goes, and put concrete in the other spaces, and carry it up, you would have a substantial job of it; and bring the concrete clear above the wood, and if you can exclude the air from the wood, you won't have much trouble.

Mr. Skeels.—You better build a new pier.

Mr. Rogers.—That means tear the bridge down and set it on shore somewhere, and quit business for a month or two.

Mr. Skeels.—That is better than to run a train into the river.

A Voice.—I should not think you would have much decay there, from the conditions you have mentioned. I should think you could depend pretty thoroughly on the soundness of the timbers.

Mr. Rogers—Decay might set in before it was dry. Decay will occur between the degrees of 50 and 120, even when it is wet, if the other conditions are favorable, and while that is perhaps not water soaked, if the piers begin to take in air and create fermentation,—if the upper two-thirds is exposed, would it absorb enough from capillary attraction to keep wet?

A. That would depend on whether the heat and wind evaporated it faster than capillary attraction would bring it up.

Q. Do you think the central portion of the platform, where it is covered with the stone work, being air tight practically,—do you think the air would work into that to any great distance, under the stone work? How long ago was that put up?

Mr. Rogers.—Seven years ago.

Q. How long has the water been low?

Mr. Rogers.—It commenced three or four years ago to show a little bit of a drop, and it has been going down three or four inches every year.

A. My opinion would be that your timber was sound but I would not go to work on it without making a test, which you can do easily by boring in there with a small augur.

Mr. Rogers.—As far as you can reach?

A. Well, you can splice your augur.

Mr. Rogers.—And hold your head under water. There are four to six inches of space between the top of the platform and the water.

A. I think it would warrant the expense of a diver. That is the only way I would see. Mr. Sears ought to know a lot about that.

Mr. Sears.—I don't think he is in any danger if he waits another eight years. It depends on the character of the timber.

The President.—Norway is pretty sappy and it would be the worst timber in Michigan to contend with.

Mr. Kellogg.—Three or four years of exposure of Norway say and I would not give much for it.

Mr. Sears.—I would give more for it in the water than in a sand bank.

The President.—The lowering of the lakes has, I guess, been a surprise to a good many of us. That was pretty thoroughly discussed last September by the Deep Waterway Convention at Cleveland. The means of overcoming it were discussed.

Has anyone anything further to offer on this question proposed by Mr. Hubbell?

Mr. Sears.—If I had that work to do,—if the wood wasn't sound enough to carry the pier,—I would put sheet piling

around there and seal it up, as suggested. I think that is the cheapest remedy for it.

Q. Can beech railroad ties be preserved and made durable by treating with coal tar and creosote, and at what expense?

A. They can be successfully treated with creosote at about $9.00 per thousand feet, board measure.

Mr. Kellogg.—Thirty-three ties in a thousand feet?

Mr. Wells.—In my paper I have taken that up. I have had no personal experience with beech ties, under the treatment of creosote. There are some others who have, however, and whose experience I have and will give you in that paper. I don't think the treatment with coal tar would be of any benefit. It would induce dry rot if the whole tie was covered; that, at least, is my opinion.

Mr Sears has been looking up the subject of ties to some extent. He can probably give us some valuable points on that.

Mr. Sears.—I think your answer is sufficient at this time, Mr. President. You fully answered that.

Q. If railroad ties were dipped in a tank of hot coal tar, and then allowed to dry, would the tar penetrate the wood or not?

A. Not to any great extent. That is taken up in this paper of mine.

ARTIFICIAL PRESERVATION OF TIMBER.

GEO. L. WELLS.

The disadvantages under which people are placed in a treeless country can hardly be imagined by those who have been bountifully supplied with forests. As we are approaching the treeless stage it is well to direct our attention to methods of preserving timber, both artificially and in the forests.

A German official who was sent to this country recently to study our forests and methods of preserving, as well as destroying them, is credited with the statement that unless radical changes were made in our methods, America would be looking to Germany for its timber supply in less than fifty years. He also charges Americans of robbing future generations of their rightful heritage by their wicked waste.

There can be no doubt but that the material progress of this country has been largely due to an abundant supply of cheap timber. Log cabins built with the crudest of tools have been a great factor in our progress, often overlooked. Had men waited until more substantial residences could have been erected, places which now support farms, cities and public works of vast extent and value might still have been a wilderness. Yet these same log cabins sheltered a sturdy population who cut and burned timber of fabulous wealth to prepare land for tillage. Lumbering operations, carried on at the same time, have made such large inroads upon forests that many men have felt great concern, not only from its effect upon floods and drouth, but as to future supplies of timber. We are all well aware to what extent these inroads upon forests have lessened the supply and enhanced the value of remaining trees in Michigan.

Some legislation has been enacted to encourage the planting of trees, but the cutting of trees or preservation of them is still largely a matter of dollars and cents. A holder of tim-

ber lands will not continue to pay taxes and let his invested capital remain longer than he can see a profitable profit in doing so. It is evident that with so many vested rights and conflicting interests among the owners of timber lands, that legislative control of forests is a matter full of vexatious problems.

The enhancing value of timber, which has caused lumbermen to go over the same ground several times, each time taking trees which before were of no commercial value, and in some places even cutting off stumps close to the ground for shingle bolts, has caused engineers and consumers of timber to give attention to the matter of artificially preserving it, when placed for use.

Europeans have given the subject more or less attention for a century, experimenting with most everything there, which has been tried in later years, so that there is really nothing very new about this subject. Lack of interest is the only reason why the subject is not better understood. The early efforts, while successful in resisting decay, were thought to be too expensive and for that reason abandoned.

The Electrical Engineers, in looking about for cheap and substantial materials for constructing conduits or subways for buried wires, have no doubt done more than all others during the last twelve years to increase interest in artificial methods of preserving wood. Railroads have given the matter considerable attention for resisting decay in ties and bridge timbers, and protecting piles from the ravages of *toredo navalis* and *linumoria terebrans* in salt water. A few cities in this country have given the subject some attention for preserving wood blocks for paving; but in Europe creosoted wood paving laid on concrete foundation is the most costly and most prized street improvement.

A tree as it is felled is composed of sap and fibre in varying proportions in different kinds of timber. Sap is found in all stages of consistency from liquid to solid, which chemists say contains, among other things, albumen, sugar, starch, tannin, resin and large proportions of water. It is the unripe part of a tree and therefore the most perishable. The fiber

contains carbon and oxygen in large quantities, and a small amount of hydrogen. When the fibre is separated from the sap it does not decompose.

The cause of decay has been attributed by all investigators to the fermentation of the sap which nourishes the germs of decay, and which in time will not only destroy the sap but the fiber as well Fermentation and decay, as is well known, are promoted when the timber is in contact with air under varying degrees of moisture and temperatures between 50 degrees and 120 degrees F. At high or low degrees of temperature, or when continually soaked in water, wood is practically imperishable.

It has been the aim of all who have experimented with artificial processes for preserving timber to stop the fermentation and kill the germs of decay. Most all materials used have been antiseptics. Short descriptions of the most noted processes will best illustrate these efforts and other items of interest.

Kyanizing was patented in England in 1832 by John Howard Kyan. His process consisted of placing seasoned timber in wooden vats with light strips between the timbers, where they were allowed to steep in a solution containing 3 per cent. of chloride of mercury or corrosive sublimate, one day for each inch of the smallest dimension. It depended entirely upon capillary attraction and timber in which the sap had been allowed to evaporate, to get it into the timber, and then when present the antiseptic qualities of the corrosive sublimate would kill the germs in the timber and those which afterwards came in contact with it. The greatest objection to Kyanizing is the poisonous nature of the chloride of mercury, its action on iron, as well as the general objection to metallic salts on account of their solubility in water, on account of which property they are so easily washed out.

General experience has shown that better results have been obtained when Kyanized timber has been used in dry places, like bridges, where it has been known to last twenty to thirty years, than in moist places like foundation timbers,

railroad ties and pavements. Kyanizing has principally been used in the eastern states in this country.

Burnettizing process was patented in England in 1838 by Sir Joseph Burnett. The earliest method was to steep timber in a solution of chloride of zinc in proportion by weight of 1 of the salt to about 33 of water, in the same manner as that described in the Kyanizing process. Subsequently timber was enclosed in cylinders, steamed and the salt forced in under pressure, as will be more fully described in the Bethell or creosoting process.

Many of the objections which have been found in Kyanizing have been urged against Burnettizing, but Burnettizing is much cheaper. Unfortunately for this process, some of the early work seems to have been hurriedly or improperly done. In one case it was so poorly done that dry rot set in. On the Boston and Albany Railroad Burnettized spruce ties lasted nine years where untreated ties decayed in about five years. On the C. R. & I. P. Railway, hemlock, tamarack, pine and cedar, under this process, were used with considerable satisfaction. The A. T. & S. F. Railroad, some years ago, tried it for ties because it was thought that the dry climate of Colorado, New Mexico and Arizona would be favorable to Burnettizing,* but it was afterwards abandoned for the Wellhouse system which had been previously tried and under which treatment ties were found good after nine years Burnettizing has also been objected to because it weakens timber.

On one of the Southwestern railroads from .70 to .50 of 1 per cent. chloride of zinc is used in treating ties.

In Germany, Burnettizing seems to have met with more success than in this country. On account of Burnettized ties decaying from the outside and creosoted ties from the heart, some of the German railroads used both methods on ties by which means the chloride of zinc could not be dissolved. The Germans use a solution containing 1 part chloride of zinc to 50 parts water by volume, and the work is done very thoroughly, oak absorbing 10 per cent. of its volume of the fluid, beech 19½ per cent. and pine 20 per cent.

*Wm. B. Sears, Chief Engineer F. & P. M., Saginaw, Mich.

On account of the soluble nature of the salt in Burnettizing a number of efforts were made to change it chemically to an insoluble compound. One process, the Thilmany, at one time gained considerable prominence. Thilmany used sulphate of copper (blue vitriol) or sulphate of zinc which was forced into the timber, then after withdrawing that solution from the cylinder, a solution of chloride of barium was forced into the timber for the purpose of changing the sulphate of zinc or copper to the insoluble sulphate of baryta; but some chemists have doubted that this chemical action took place under those conditions. From a recent letter to the writer by G. H. Benzenberg, City Engineer of Milwaukee, the following is extracted: "In 1876 we laid quite a considerable amount of four-inch blocks six inches deep, the blocks having been treated by the Thilmany process. This paving gave us excellent service for ten years, and was finally taken up in the center of the roadway for a width of twenty feet because of the wear of heavy travel instead of deterioration due to decay. The blocks when taken up were apparently as sound as the day they were laid and in some portions of the streets the blocks are still in the pavement next to the curb where the travel has not been so great. I am fully satisfied that if the treatment is thorough and careful, that the extra cost of preparing paving blocks by that process is the most economic investment of the pine block pavement. The trouble here was that they had so much work to do that they became careless in abstracting all sap thoroughly before impregnation was begun."

The Wellhouse process employed chloride of zinc with glue and tannin to prepare the timber so as to retain the salt and the Hagen process used gpysum for the same purpose.

The Boucherie process was used to a considerable extent in France about 50 years ago, but so far as the writer has been able to learn, found little favor in other countries. It depended on vital suction in live standing timber, taking up a solution of sulphate of copper. As it can only be carried on a part of the year and in remote places it would find little favor in this country where lumbering operations are pushed so rapidly,

and especially where logs are transported by floating in streams.

The vulcanizing process treats timber placed in a retort with heat up to 500 degrees, coagulating the albumen, and producing chemical changes in the wood to stop decay. It is also claimed that this process seals the pores. Timber treated by this method has not had the wide application and test of time to prove its efficiency that the older methods have had. As vulcanizing at such a high temperature is a partial distilation of wood, more or less acetic acid would be formed, which would make conduits treated by this method unfit for holding electrical cables, because of the destruction of the lead covering by acetic acid.

Many methods employing charring, carbonate of soda, crude petroleum, arsenic, resin, soap, sulphate of iron, nitrate of silver, lime, salt, and various other substances have been experimented with.

Here in the Saginaw Valley the effect of salt in prolonging the life of timber is quite well known. As chloride of zinc-creosoting process has been used to advantage in railroad ties, the writer can see no reason why chloride of sodium-creosote process could not be used with equal advantage, and at less cost.

The subject of cheap timber preservation seems to have employed about as many, and as crazy a lot of inventors as has perpetual motion, with like results, when homœopathic doses of antiseptics were used. Nothing but thorough treatment with liberal use of antiseptic will do.

The writer's experience has been with the Bethell or creosoting process which was patented by Mr. John Bethell in England in 1838, and has been extensively used ever since. As the creosote was cheaper and more plentiful in Europe than in this country, it was more commonly used there than here until recently.

The general experience with the three leading processes was thus summed up by the late James B. Francis, a past President of the American Society of Civil Engineers, in a discussion in 1885: "There can be no doubt about the preservative effects

in lengthening the life of wood either by Kyanizing or Burnettizing. We have found that Kyanizing answers our purpose the best, and we have followed it ever since. My experience has been long enough to leave no doubt whatever about it; it extends from 1848 to this time (37 years). Creosoting, I have no doubt, is a still more perfect preservative, but the expense and difficulty of doing it, prohibit its use to a great extent. Kyanizing is only a preventative of rapid decay, that is all that is claimed for it; it delays the decay."

The creosote or dead oil of coal tar has become much cheaper since then, now being worth about $9.00 per B. M. for a treatment of 15 pounds per cubic foot.

The process consists of placing the timber, separated by lath, on cars, which are run into a heavy cylinder, and which is closed by heavy cast iron doors securely bolted. Live steam is turned on with a temperature of 225 to 250 degrees F. until the timber is heated through thoroughly, coagulating the albumen in the sap. A vacuum is then formed to extract the sap. The cylinder is then pumped full of the dead oil of coal tar, then, from a measured tank, the required amount of the oil is forced into the timber under a pressure of about 100 pounds per square inch.

The open grain timbers when saturated take about thirty pounds of oil per cubic foot, and is required only in a few cases for piles to be driven in salt water. For other work, from 8 to 18 pounds are required; 12 and 15 pounds being most commonly called for in specifications.

The dead oil of coal tar weighs about 8.8 pounds per gallon. It is obtained by distilling the residual product of coal gas, and is taken off between about 450 to 700 degrees F., which vouches for its non-volatile nature.

It contains among other things naphthaline, carbolic and cressylic acid, strong antiseptics. Besides the antiseptic qualities of the oil it is insoluble and heavier than water and can neither be displaced nor washed out by it. The outside of timber treated by the Bethell process varies in a color from a very dark brown to black, white crystals form on the outside, more so in cold weather than in warm. The dark color does

not extend far into well treated timber. It forms a sort of a thick skin which should not be broken. There is no doubt but that the reason why railroad ties do not last so long as other creosoted timber is because the adz is so frequently used, cutting into ties by wearing of rails and pulling out spikes. Leaving the old spike hole open, leaves exposed places under the skin which are attacked by germs, and which could be materially remedied by painting with the oil or plugging spike holes with creosoted pins.

The best effect is upon the more open grained or cheaper timbers. Michigan Norway pine is admirably adapted to this process.

The general benefits can best be shown by giving different experiences in more or less detail.

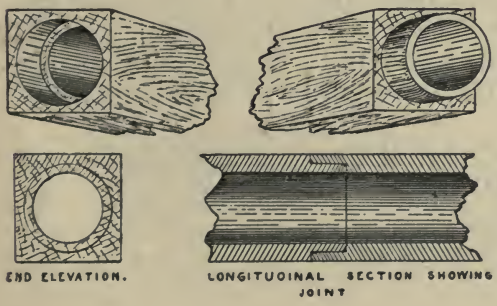
About twelve years ago cities began compelling corporations using electric wires to bury them. Electrical Engineers tried to find conduits for the cables which would be at once cheap, durable and have good insulation. The New York and New Jersey Telephone Company, of Brooklyn, was about the first company to bury their wires, and after due investigation adopted wood treated with dead oil. They now have about 155 miles of the conduit in use. An examination made last summer of the first conduit laid in 1884 showed no signs of decay in the wood nor deterioration in the cables, and has received the unqualified endorsement of that company. This company found that by alloying 3 per cent. of tin with the lead covering of the cables, the covering was not at all affected by carbonic acid and other gasses naturally arising in the trenches and manholes.

A similar experience has been found in Philadelphia by the various light, telephone and street railway companies, and the City Electrical Bureau. There are over 600 miles of conduit used in Philadelphia, most of which has been creosoted. Chicago is beginning to use it extensively. It is being used in a large number of New England towns. A few years after the practice of burying wires was inaugurated, some Boston gentlemen, in order to get conduits at a reduced cost,

had some wooden tubing treated in the south with a compound obtained from distilling wood, and called "Kreosote."

In the distillation of wood, acetic acid is as certain a product as charcoal and this "Kreosote" was impregnated with it. It was found that the acetic acid present in the conduits when laid, attacked the lead covering of the cables, reducing it to acetate of lead. The carbonic acid gas arising from the trenches, again liberated the acetis acid, and this sort of perpetual motion was kept up until the cables were destroyed. An attempt was made to stop the chemical action by injecting asphaltum dissolved in bisulphide of carbon into the conduits. The æsthetic nostril of the residents of the "Hub" were so offended that they at once sought an explanation from the man who had the matter in charge. Unfortunately for him and his scheme, too, he was afflicted with an impediment of speech which added to the complications to such an extent that the poor fellow had to leave town to escape being mobbed. It was some time before the actual cause of the trouble became generally understood. Firms who manufactured conduits of other materials, took advantage of this mishap and circulated the story industriously, seeking to confound the compound obtained from distilling wood with dead oil of coal tar, which is not only a preservative of wood, but of metals as well.

The same company who had this unfortunate experience are now using large quantities of conduit treated with dead oil of coal tar. The American Bell Telephone Company (the parent company) have endorsed it after a thorough investigation.



The usual form of the conduit is square 4½x4½ inches, 4x4 inches, 3½x3½ inches and 3x3 inches with holes 1½ inches less in diameter. The lengths are 8 feet and are jointed with a mortise and

tenon joint as shown in the cut. They are laid on creosoted boards usually 1½ inches thick for a foundation, and are covered by a creosoted board to protect them from blows of tools in hands of workmen employed in subsequent improvements.

Creosoted telegraph poles* in England showed no signs of decay after 35 years, and in Mississippi creosoted poles in use 15 years showed no signs of deterioration.

Poles driven in salt water have been treated with dead oil of coal tar to repel the attacks of the *toredo navalis* and *limnoria terebrans*. If enough oil is injected the protection is permanent, but this hardly interests us who live on unsalted seas.

Railroad ties treated with the dead oil of coal tar have met with a great deal of success in this country and Europe.

In answer to circulars sent out by Mr. Bogart, when Secretary of the American Society, it was found that many ties were sound after 22 years' use. In this country 19 years seems to be about the average life of well treated creosoted ties.

The following is extracted from a letter under date of December 2nd, 1895, from Mr. R. Montfort, Chief Engineer of the Louisville & Nashville Railroad company. "We still have a large amount of creosoted timber on our New Orleans & Mobile Division which was put in during the later seventies, (began in March, 1876),† with the exception of a small number of bridge ties which rotted and were removed the last year or two. Practically all the creosoted timber is still sound. The rotting of the ties is largely due to the fact that we changed the gauge of the track from five feet to four feet nine inches, thus cutting up the ties with additional spikes and allowing water to get into the old spike holes; and also to the fact that the rail has cut into the ties, due to the traffic."

These ties were treated with 15 to 16 pounds of oil per cubic foot, and most of them showing 18 to 19 years' use, and are still serviceable.

On the Central Railroad, of New Jersey, during the year 1876 they put about 5,000 creosoted ties in their main tracks,

*N. W. L. Brown in Electrical Railway Gazette, Oct. 19, 1895.
†Proceedings Am. S. C. E., June 1885; p. 335.

west of Bound Brook. None of these ties were taken out until the year 1888, when about ten per cent. of them were removed. * * * * They experienced no particular trouble on account of spikes not holding. The last of the ties were taken out last summer. Here is about 19 years' use.

It has been found in railroad work that timbers treated with the dead oil of coal tar are not weakened.

The application of the Bethell process to paving blocks seem to have been beneficial. Paving blocks cut out of timber from which the sap wood has been removed, because of being softer than the body wood, and laid with close joints has given good results. Concrete foundations are desirable.

The following is taken from a letter from Mr. B. M. Temple, City Engineer, of Galveston, Texas, under date of December 25th, 1895: "In 1874 several blocks of creosoted short leaf pine sawed block paving was laid on the principal street here, and is in perfect repair and condition. I saw some of the blocks split open last spring and they were perfectly sound. Wedges were used in that pavement but several miles have been laid recently without wedges. The Island being composed of fine sand forty feet in depth, the blocks were laid directly on the sand after it was thoroughly wetted down.

"The recently laid blocks are of long leaf pine and all the blocks are laid 6x6 inches—I do not know how much oil was put in the blocks, having only been City Engineer since last June. I have lived here since 1877, engaged in constructing railroads."

The writer has one of the blocks from Galveston, which is in perfect condition as far as decay is concerned, and shows only half an inch wear. This short leaf Texas pine has the reputation of decaying in two years in its natural or untreated state.

The following is from a letter dated December 6th, 1895, from I. D. Fletcher of New Orleans, a manufacturer of chemical products of asphaltum and coal tar: "Seventeen years ago we paved the roadway of the N. O. Gas Company with creosoted wood blocks and they are as sound as a rock to-day.

"This pavement has had more traffic over it than any other street in the city, as there has been almost a continual line of carts loaded with coal going over it every day since put down. A few months ago we took up some of these blocks to put in our exhibit at the Atlanta Exposition, and found them as they were the day they were put down, except about ¼ inch worn off the top from friction of the cart wheels.

"In answer to your questions, will say, blocks should be treated with about 16 pounds of oil to cubic foot. Size used, 4x6 inches, 4x4 inches and 3x4 inches. We have used long leaf yellow pine to best advantage. For block paving, the heart only should be used on account of its standing wear better than sap, but for post and piling, sap is better because it takes more oil. Blocks not creosoted last about two years."

At the risk of departing a little from his text, the writer has thought it best to collect and give some information on creosoted wood paving, which sometimes deals with comparisons of stone and asphalt.

Birmingham, England, had 169 miles Macadam, 28 miles granite, and 7 miles of wood pavement of creosoted yellow deal (pine) blocks laid on foundation of Portland cement.*

Creosoted blocks are laid on concrete 6 inches to 9 inches thick (7 broken brick or slag; 1 cement), finished off with a smooth, clean surface upon which the blocks are laid without sand or ashes. Double layers of planking crossing each other diagonally have been tried and abandoned. The blocks are creosoted yellow deal 6 inches deep by 3x7 inches, laid in courses ¼ inch apart, blocks having butt joints longitudinally. Spaces between courses are filled with grout of 1 part Portland cement to 2 parts of sand.

The traffic of Birmingham is so heavy that blocks wear out before decay sets in. Street grades are too heavy to admit of the use of asphalt.†

DUBLIN, IRELAND.—The paving in Dublin is mostly stone, but in the principal thoroughfare, which is narrow, and in a few others, the pavement is wood. Wood paving is also used

*Special Consular Reports, Streets and Highways in Foreign Countries.
†W. S. Till, C. E., City Surveyor, Birmingham.

opposite a large number of churches and hospitals to avoid the noise of traffic, in preference to other forms of street paving. Archangel red blocks, 5″x9″x3,″ containing 10 pounds of dead oil of coal tar to the cubic foot, have given the best satisfaction. The foundation is concrete (6:1). Blocks are laid as closely as possible to maintain straight joints throughout. Into the lower half of the joint is poured a hot mastic of creosote, Limmer rock asphalt and coal tar. The upper part of the joints are filled with liquid cement grout (1 cement; 3 sand). The foundation is allowed to stand seven days before the blocks are laid, and the whole finished pavement stands another period of seven days before the street is opened for traffic.

As is generally the case in Europe, the paving wears out before any signs of decay set in. Here, the time is from 8 to 12 years.

Beech blocks were tried, but found to decay because the timber was not felled in the proper season and decay set in.

"I think there are many considerations, such as the effect of climate, difference of traffic, local causes and regard to cost, which must render wood pavements more desirable in some cities than in others."*

The writer is of the opinion that had the beech blocks been steamed, as is the practice in the United States, and the oil forced into the blocks under pressure, this would not have occurred. In applying oil to timber by absorption, there is always the danger that the blocks have not been properly seasoned and dry rot might take place.

FRANKFORT-ON-THE-MAIN, GERMANY.—In Frankfort-on-the-Main, the "Zeil," the principal thoroughfare, was partially paved with wood, German beech and pine, Swedish Pine, American cypress and pine, free from sap, a part of which were impregnated by different methods and part not impregnated at all, and laid on a solid impervious concrete foundation, have given uniform success.† The work was all well and thoroughly done, and while it speaks well for wood pavements

*Spencer Aarty, City Engineer and Surveyor, Dublin.
†Special Consular Reports, Streets and Highways, &c.

generally, the information as to any preserving process is indefinite.

Herr Heinrich Lonholdt of Frankfort-on-the-Main, believes that creosote oil is the best preservative of wood, but that "pickling" answers every purpose. Herr Lonholdt is connected with the "system-Kerr," a German paving, using wood blocks "pickled" in creosote. He has expressed an opinion that Michigan pine is well adapted for paving.

HULL, ENGLAND.—"Granite and wood pavements and Macadamized roads are used in city and districts."

"In wood pavement, which gives much satisfaction in this country, a foundation of cement concrete is formed, 7 inches in thickness, composed as described in granite pavements." Blocks are of red wood sawed square, 9″x3″x5,″ the grain of the wood running with the 5 inch measurement. Courses are laid ⅜ of an inch apart, held apart by lath. Joints filled up with shingle to a level of 1 inch below surface, and remaining space filled with asphalt.

LIVERPOOL, ENGLAND.—This city had in December, 1895, 13,236 square yards of creosoted Baltic red pine, elm, greenheart and pitch pine pavement. 1,367 square yards of creosoted Baltic red pine laid in 1875, on which there was an average traffic of 302,000 tons per yard width, per annum, will need to be renewed shortly—a little over 20 years' use.

4,250 square yards of creosoted Baltic red pine laid in 1874, on which there has been an average traffic of 94,000 tons per yard width per annum, will require a large portion to be renewed—over 21 years' use.

Creosoted elm wears out in Liverpool much faster than the Baltic pine, it having lasted 10 to 13 years. The life of pavements depends entirely upon the amount of traffic. Blocks are 3 inches thick, 9 inches wide and 6 inches deep, and creosoted with 10 pounds of dead oil of coal tar per cubic foot of timber.*

KENSINGTON, LONDON, ENGLAND.—"All the main roads are paved with wood except about 1,000 square yards of asphalt.

* H. Percy Boulnois, City Engineer, Liverpool, England.

The whole of the wood pavement is laid on a foundation 6 inches thick, of concrete composed of Thames ballast and Portland cement, 6 to 1. Over 200,000 square yards of wood have been laid in Kensington, and I* have tried various kinds of wood, including the ordinary fir deals, beech, vale and Jarrah, out of depths varying from 3 to 6 inches, and have laid the blocks in a variety of ways, close together, with open joints grouted with different materials, with felt joints laid on asphalt and on felt, plain deal blocks, creosoted blocks, naphthalized blocks, etc., etc."

About 10½ pounds of creosote is forced into each cubic foot of wood. Streets paved with 5 inch blocks last 10 years. Thinner blocks can be used on the sides than in the centre of the street.

The following table, taken from the report of William Haywood, Engineer and Surveyor, Guild Hall, London, to Consul-General New, on 50 days' observation, shows comparative slipperiness of pavements, showing how many miles a horse might be expected to travel before meeting with an accident:

1. Granite.....132 miles.
2. Asphalt.....191 "
3. Wood.....446 "

London surveyors and Engineers, among other reasons, favor creosoted wood pavements because it is quieter than either asphalt or granite.

Small blocks with close joints give best results for even wearing and cleanliness.

Some pavements are formed of fir blocks 3½″x6″x10″ and laid on two thickness of plank well pitched and nailed together.†

"The wood used for paving carriage ways in London consists principally of yellow deal blocks, plain or creosoted, 9″x6″x3,″ and Jarrah and Karri (Australian) wood blocks, plain or creosoted, 9″x5″x3,″ laid on foundations of Portland cement concrete (6 or 8 ballast to 1 of cement) 6 inches in

*William Weaver, C. E., Surveyor, Town Hall, Kensington.
†Special Consular reports, Streets and Highways, &c.

thickness, with spaces between the blocks, into which bitumen or grouting is run, and the whole is then covered with a thin layer of fine ballast.

"A cubic foot of yellow deal, cut into blocks, will absorb about 12 pounds of creosote, but the Australian woods, being harder, do not absorb above 6 or 8 pounds per cubic foot. The wood blocks do not decay if properly laid, that is to say, so as to prevent water from getting underneath them."

"It is usual in putting down wood paving, to allow a space of about 2 inches on either side of the carriage way between the blocks and the curb, and which space is temporarily filled in with sand or fine ballast so as to admit of the expansion of the wood after the vehicular traffic is turned on to it."*

MANCHESTER, ENGLAND.—"We have several lengths of street, containing a total area of about 6,500 square yards, paved with creosoted beech blocks. Our specification for the block is as follows:

"English beech wood block, 6 inches to 11 inches long, 3 inches wide and 6 inches deep, the same to be well seasoned and free from sap, and creosoted with 10 pounds of the best creosote oil to the cubic foot of timber.

"The blocks are paved with close joints, on a foundation of cement concrete six inches or more in depth, according to the requirements.

"In this city creosoted beech blocks have lasted about 10 years, and generally speaking, if the blocks are properly creosoted, they wear out before decay sets in."†

In Sheffield, England, some Baltic red timber or yellow deal, free from sap, creosoted with 8 to 9 pounds dead oil of coal tar per cubic foot, laid on concrete foundation, lasted 9 to 10 years. Beech wood had been employed, but was dearer than red wood or yellow deal (pine).‡

Creosoting prevents blocks from swelling when laid and subjected to heavy rains. The sizes of blocks used are 3″x9″x6″ and 3″x8″x6.″ The last dimension running with the grain.

---

* Alexander R. Binnie, C. E., Spring Garden, S. W. London.

† M. S. Massey, Chief Clerk Department Paving and Highways, Manchester.

‡ Special Consular report, Streets and Highways, &c.

The latter size is used in breaking joints. No spaces are left between blocks now. Each block is dipped 4 inches into a bath of hot pitch and tar and laid and wedged together. Blocks wear out before decay sets in.*

BERLIN, GERMANY.—The pavements lately laid are of Swedish pine blocks, 13 centimeters (5⅛ in.) high, 8 centimeters (3$\frac{3}{16}$ in., nearly,) wide, and 18 to 25 centimeters (7⅛ to 9⅞ in.) long, impregnated with creosote. After treatment they are sorted into three classes. The first class to be used in the middle of the street and where there is the most travel. They are sound and free from sap. Blocks are laid with spaces 8 to 10 m. m. ($\frac{5}{16}$ to ⅜ in.) between them, a lath 8 m. m. being used to get even spacing, but it is removed after the pavement has been laid. When this is done, fluid cement is poured in over them and the top strewn with crushed porphyry. This last process is repeated every four years.

On either side of the pavement, for a distance of 4 centimeters, ($1\frac{7}{16}$ inches), clay is placed, extending to the sidewalk, so that there may be an expansion without bulging of the blocks. Blocks are laid on a concrete foundation 20 centimeters (7⅞ in.) deep.

There are several creosoting plants on the Atlantic Coast and a few in the South. The only one in this State known to the writer, is that of The Michigan Pipe Company, Bay City, Michigan, built under specification prepared by him early in 1894.

No attempt has been made to give numerical demonstrations of the economies derived from using creosoted timber. It is apparent to any observer, and economies can be easily worked out for any particular case or locality.

---

*Chas. F. Wike, City Surveyor, Sheffield, England.

NOTE.—The writer of this article has been indebted to the Transactions of the American Society of Civil Engineers, June, 1885, for much of the historical matter and descriptions of some of the processes now obsolete. Other interesting facts have been obtained through correspondence, for which due credit has been given.

SPECIAL ASSESSMENTS--SURVEYOR'S TAX.

E. STRONG.

The object of this paper is to present one method, the form used and object aimed at in that division of special assessments known as Surveyor's Tax.

It will not be claimed that these forms are complete in themselves, or should replace other forms which have long been used with good results. They have been used by the writer and others, for twenty-five years or more, and with complete success in every instance. During my life I have never known of one dollar failing in a Surveyor's Tax.

I have also been unable to find serious legal criticisms pertaining to this tax, after examination of Michigan Reports.

I once heard a circuit judge refuse to entertain objection to a tax title deed because it was based on a Surveyor's Tax. And the court made the further statement that the legality of a Surveyor's Tax had often been tested in the supreme court, and had never suffered an adverse decision, and was just as legal as a supervisor's tax and for the same reason, because it was provided for by statute.

I have known another case of 160 acres of land to be sold to satisfy a Surveyor's Tax of six dollars. This was approved and returned by the Auditor General, the land was bought by a stranger, and ten years elapsed before it made trouble.

The chief reason to justify a Surveyor's Tax, to collect a private debt, seems to be that the statute requires the surveyor (at least the old law did) to perform the duties of his office when application is made to him by any court, or any officer of the court, or any other person. To compensate for this last requirement, it has seemed to me, the surveyor was

allowed to certify his bill to the supervisor. In Public acts of Michigan, 1895, the words "any other person" were omitted.

Two months ago a man, notorious for never paying a bill, applied for a line between himself and neighbor. The surveyor objected for financial reasons. He said: "You have got to come, anyway." The reply was: "I suppose I have." He has not yet paid his taxes, but he will.

PETITION.—A written application and notice of ten days are unnecessary when the parties are all present in the survey, or present in the petition, or consent in other ways. Of course, this condition exists when only one or two are interested. But in case of a neighborhood quarrel a survey to tax should be made with more caution.

Petitioners are required to give notice, but it is better for the surveyor to take names and addresses and notify all at once by mail, keeping a record of the same, and filing the petition. Notice is required only to those living in the same township, but sound sense will give everybody notice. Even when there is no tax, the surveyor should ask to have others notified.

When the owner of a single piece of land applies and neglects payment, I suppose the tax is good, especially if it cannot be collected in a different way. But I have never assessed the platted lots of a village. Unless requested to put it in the tax, the surveyor has also a right to bring action for debt. But it would seem that the statute gives the petitioner *the right* to pay his bill in his tax, if he requests it, and I doubt whether he can be deprived of this right.

If the tax is not spread the following last Wednesday in September and the land is sold to other parties, the levy cannot be enforced. However, it will probably be collected and that will be the end of it.

By permission of the supervisor I have put in a bill as late as November 11. And many times a small tax has gone over two or three years and will make no difference, unless in the meantime the land has changed hands. In one case last year a piece of land was divided into three parts, and deeds given immediately after. The parties agreed among themselves to

furnish the help and the seller was to pay the survey bill, but some time after declined to do so. This bill went in the first year, and was an injustice to the buyers. It certainly could not go in the second year.

If application is made to the surveyor and he is requested to apportion and tax, he has no discretion in the matter and must do so. Neither has the supervisor any discretion. His duties are simply clerical, and he cannot look behind the surveyor's certificate and assessment roll. However, he is very apt to do this very thing; not because he is well posted, but because he knows nothing about it. The surveyor must treat this thing very leniently, answering questions fully, whether proper or not, and making the further statement that the tax is all right, and that the surveyor and not the supervisor is responsible for it. In all cases, reference should be given in the warrant to the statute under which he acts.

One supervisor the past fall on receiving by mail a bill to spread, said: "Why! is it not an unheard of thing that anybody in the world can send a bill to the supervisor and have it put in the tax? Where do you get your authority for any such thing?" The surveyor replied that in the warrant itself, reference was made to the statutes providing for it. After looking it up he said it was all right, but a new thing to him. "But why should the surveyor be allowed to collect *his* bills in the tax any more than doctors or lawyers?" The answer given was that service was compelled where pay could not be collected in any other way, and the statute saw fit to provide this relief. It is also a benefit to the public to equalize the cost of the subdivision of land and not compel the few to furnish the boundaries to others.

He also learned that there was one tax that did not come to him through the township clerk.

Apportionment has been discussed by this society in previous years. The statute requires it to be made in the proportion to the work done for each description, to be determined by the surveyor. But method and practice varies widely in its details. Some have apportioned evenly between the parties; and it cannot be denied that there are many cases

where this is right, probably one-half of all. Sometimes it can be based on acreage; other things being equal, this will answer. But they are likely to be unequal. Others apportion according to work, and acreage and numbers to pay, are important factors in the problem. But the problem is by no means a difficult one. It matters little by what mental process the result is reached in each case. As to myself a random line is run and then corrected. By this I mean an offhand apportionment, covering the bill. Then take from one piece and place upon another, until the roll is equalized.

ORDERS The law of 1895 makes it the duty of the surveyor to draw orders on the county treasurer for himself and others. Heretofore orders were given in the same way, on the township treasurer, without the law expressly saying so. These orders were placed on the same sheet as the assessment roll of the surveyor. And the book of the treasurer should show the same thing. It does not always do so and a new township treasurer is likely to ask for an order from the township board, or clerk, or somebody, and the surveyor will find it necessary to talk a spell, or go home without his pay. He will not easily believe that the surveyor can draw his own order, and spread his own tax, and that, too, without review, and without reporting it to the township clerk. I acknowledge that it is an anomaly in the way of taxation. But the law of '95 has done away with this uncertainty, and placed in plain language the practice of former years.

It has done another very excellent thing. Heretofore, the surveyor has been obliged to go after his pay. No matter how far away the township and treasurer, he must hunt him up and if gone from home, wait his return. Thus, if the bill was small, he earned his money the second time, or let it go altogether. Hereafter, the surveyor will draw his order on the county treasurer, once for all, thereby saving time and breath. (Some bad breath). This is the most important change in the law of recent years, and every surveyor in Michigan will take pleasure in making use of this provision.

ITEMS OF THE BILL TAXED.—Discussion in this society will develop the fact that there is some difference in practice

among surveyors in the items of the bill taxed. His time at four dollars, the time of the chainmen at local rates, the record of each description in the land surveyed at 25 cents each, will not lead to any serious disagreement. But when it comes to 25 cents, also, for each corner established or perpetuated and recorded, there is a chance for a question. So far as I know, this is the practice in our own and adjoining counties. One counts the planting of a stone because he has established a corner, and another man counts it because he calls it a record. Perhaps both are right. I do not know.

The pay of other helps than the chainmen should not go into the bill. I understand that the courts have quite uniformly drawn a line of distinction between chainmen and other help. Someone may be able to show that the courts do no such thing. I should like to know.

One sample of a section surveyed and taxed under petition for the same is given below, with the form of petition and warrant or certificate. Also the items of the bill, together with the apportionment, names and orders. This sample is given to present one case in full, right or wrong. Approved or criticized, it is of no account in itself, but inexperience may prize it.

PETITION.

We, the undersigned, a majority of the resident owners of land on_____, Section_____, in the Township of_____, having given ten days' notice to all other persons, or to their agents, owning land in the same section, who reside in the township, desire you to locate and establish our corners and lines in accordance with the statute in such case provided.

ITEMS OF BILL.

Time, 3 days	$12.00
22 corner stones @ .25	5.50
Moses Osborn, 2½ days	5.00
Allen Owen, 2½ days	5.00
May 2, Searching Records	2.00
13 Records @ .25	3.25
Total	$32.75

CERTIFICATE.

KALAMAZOO, Sept. 1, 1893.

_____, Supervisor Township Texas.

Dear Sir: There are due me the following sums of money for surveying lands in your township. I have apportioned the same as required by law (see Session Laws of '71 and '69) at the request of the parties employing me. I shall be entitled to have the same levied and collected on the within described portions of land.

SURVEYOR'S TAX, SEC. 16.—APPORTIONMENT.

Powers, Mrs.	
53 a, n ½ of n e ¼	$ 3.80
Root, C. C.	
40 a, e ½ of s ½ of n e ¼	2.88
and n e ¼ of s e ¼	.57
Britton, B.	
32 a, w ½ of s ½ of n e ¼	2.30
Harvey, P. N.	
34 a, n w ¼ of s e ¼	2.45
Kelley, K.	
17 a, s e ¼ of s e ¼	1.23
Parsons, W.	
35 a, s w ¼ of s e ¼	2.52
Conlon, P.	
58 a, n e ¼ of s w ¼ and	
s e ¼ of s w ¼ except 22 a	4.17
Hanna, J.	
57.10 a, s w ¼ of s w ¼ and 22 a of s e ¼ of s w ¼	4.10
Harvey, C. A.	
40 a, n w ¼ of s w ¼	2.88
Harvey, J. 39 a	2.40
Crandall, Mrs. Chas. 33 a	2.50
Stratton, M. B. 10 a	1.00
Total	$32.80

ORDER.

The treasurer is hereby directed to pay from this fund without further order from me to, M. Osborn, $5.00; Allen Owen, $5.00.

E. STRONG, County Surveyor.

LEGAL DECISIONS.

BOUNDARIES.

1. Where adjoining owners erect buildings with reference to the supposed boundary line between them, there is a practical location of such boundary.—[Ford v. Schlosser (Com. Pl. N. R.) 34 N. Y. S. 12.

2. Where owners of adjoining tracts plat them with reference to a certain line, which they recognize as a section line, the boundaries of the streets and lots so fixed will not, more than 50 years thereafter, be disturbed, though the true location of the section line be other than that recognized.—[Butler v. City of Vicksburg (Miss.) 17 So. 605.

3. Where the monuments established by a plat are those fixed by the government survey, and those making the dedication in the actual location of the lines of the plat included within the lines of private property a strip of land which, according to the true location, is within the boundaries of the street, the government monuments prevail.—[Brown v. City of Carthage (Mo. Sup.) 30 S. W. 312.

4. In case of a disputed boundary line, where the plaintiff's field notes call for a line the location of which subsequent surveys have changed, and also for a corner which corresponds with the later location of such line, and with calls for distance and other surveys, the first-named call must yield.—[Layton v. New York & T. Land Co. (Tex. Civ. App.) 29 S. W. 1120.

5. The official plat of a township showed that sections 23 and 26 are fractional, bordering on a river on the west; that a meander line runs through them; and that the area of certain lots in such sections is 170.42 acres. In fact, along such meander line is a bayou, west of which, between it and such river, is a body of land over a mile wide, containing 600 acres, which was never surveyed. The length of the section line between such sections, from the east line thereof to the meander

line, is given on such plat as 30.55 chains, while the distance from such east line to the main body of the river is about 1½ miles. *Held*, that such bayou, and not the main body of the river, is the boundary of such sections and lots, and that a patent of such lots "containing 170.42 acres, according to the official plat," did not convey the land between the bayou and the main body of the river.—[Horne v. Smith, 15 S. Ct. 988.

6. The owners of city lots had for 35 years maintained a fence between their lots and the street, and the city had acquiesced therein. The marks of the original survey having been destroyed, a resurvey was made on the theory that the original survey was wrong, and should be corrected. *Held*, that the fence was better evidence than the resurvey as to the location of the line between the lots and the street.—[City of Mt. Carmel v. McClintock (Ill. Sup.) 40 N. E. 829.

7. In locating the northwest corner of a section of which the northeast corner can be located, it is error, instead of merely following the calls of the division survey of the township, to start from a subsection corner in an adjoining township subdivided under a different survey, and thence run a mile and a half, only connecting the subdivision surveys of the two townships by assuming that their section corner stones on the township line coincide.—[O'Hara v. O'Brien (Cal.) 40 P. 423.

8. A deed conveying land bordering on a stream, and defining its boundaries as "commencing at the intersection" of a certain ditch "with the shore line," and extending by courses and distances named to the "S. shore" of the same stream, "thence along said shore as it winds and turns to commencement," made the shore line the boundary, and did not convey the land lying between the low-water mark and the thread of the stream.—[Freeman v. Bellegrade (Cal.) 41 P. 289.

9. Where a fractional lot is conveyed, the grantee is bound by the distances given, even if reference is made to an official map.—[Hostetter v. Los Angeles Terminal Ry. Co. (Cal.) 41 P. 330.

10. Where land conveyed forms a triangle, and two sides and the acreage are given, a straight line from point to point will be adopted as the third side, when the boundary thus formed will enclose the number of acres called for.—[Hostetter v. Los Angeles Terminal Ry. Co. (Cal.) 41 P. 330.

11. Where three sides and the number of acres are known, and it is disputed whether the fourth side is a straight or meandering line, the straight line will be adopted, when the tract thus enclosed contains the number of acres called for, and when the acreage would be largely increased if the meandering line were adopted.—[Hostetter v. Los Angeles Terminal Ry. Co. (Cal.) 41 P. 330.

12. A meander line merely determines the sinuosities of the stream or body of water, and is not a boundary.—[Schlosser v. Crookshank (Iowa) 65 N. W. 344; Caldwell v. Jackson, Id.; McNary v. Same, Id.

13. In the absence of evidence of a reservation in the patent or an assertion of title by the government to land lying between the meander line of a lake, as established by its surveyors, and the shore line of the lake, evidence aliunde is inadmissible to show that the meander line was intended as the boundary of the adjoining patent.—[Schlosser v. Crookshank (Iowa) 65 N. W. 344; Caldwell v. Jackson, Id.; McNary v. Same, Id.

14. Where parties by mutual agreement fix a boundary line, and thereafter acquiesce in the line so established, such line will be considered the true line, though the period of acquiescence be less than that fixed by statute for gaining title by adverse possession.—[White v. Peabody (Mich.) 64 N. W. 41.

15. Where there is a conflict between field notes and the original monuments, the field notes must yield to the monuments.—[Robinson v. Laurer (Or.) 40 P. 1012.

16. Where stakes are found at points so as to conflict with the field notes, the burden of showing that the stakes were monuments of the original survey is on the party claiming to the stakes.—[Robinson v. Laurer (Or.) 40 P. 1012.

17. When a southern boundary is described as beginning at a certain corner; and running "thence east to the southwest corner of the land of C.," such corner becomes a monument of description; and, if its location is definitely ascertained, the boundary would be indicated by a straight line running from the point named to the southwest corner of C.'s land, though the line would run in a southeasterly direction, and the quantity of land conveyed would be about 35 acres, instead of 30 acres, more or less, as given in the conveyance.—[Abbey v. McPherson (Kan App.) 41 P. 978.

18. That a fence is on the true boundary line between two farms cannot be shown by evidence that it is in line with fences on adjoining farms.—[Fuller v. Worth (Wis.) 64 N. W. 995.

DEDICATION.

1. User of land for the statutory period as a public highway conclusively establishes dedication of the land for that purpose.—[Campau v. City of Detroit (Mich.) 62 N. W. 718.

2. Where the public has acquired an easement by user in a highway, the listing of the land for taxes and payment thereof by the owner does not effect the rights of the public in the land.—[Campau v. City of Detroit (Mich.) 62 N. W. 718.

3. A conveyance of lots as bounding on a street, laid out over the grantor's land on a public or private plat, but not opened, is, as against the city seeking to take the land occupied by the street for street purposes without compensation, a dedication of only so much of the land occupied by the street, in either direction, as will enable the grantee and his successors to reach some other opened or unopened public way.—[City of Baltimore v. Frick (Md.) 33 A. 435.

4. Where land was clearly dedicated for a street, it was not necessary that it should be accepted by the public, or used for that purpose, within any limited time, in the absence of a condition to that effect; and hence mere lapse of time of 23 years, without acceptance or user, did not constitute an abandonment.—[City of Baltimore v. Frick (Md.) 33 A. 435.

5. The facts that the bed of the street was from time to time dug up for clay, and that a brick kiln was located on a

part thereof for 18 years, did not nullify the dedication.—[City of Baltimore v. Frick (Md.) 33 A. 435.

6. Mere use of a road over private land by the public will not make it a public road.—[Dicken v. Liverpool Salt & Coal Co. (W. Va.) 23 S. E. 582.

7. Where a narrow strip beside depot grounds was unin-closed by lines of the town plat, and several streets opened into it, and lots abutted on it, which, unless it was intended for a street, would have no access to any street except through an alley, there was a dedication of the strip to public purposes, though it was not so designated on the plat.—[Arnold v. Weiker (Kan. Sup.) 40 P. 901.

DEED.

1. Where a deed contains two descriptions, each com plete in itself, of the land conveyed,—one of the descriptions including all the land included in the other, and more besides, —the deed passes title to all the land contained in the larger tract.—[Lake Erie & W. R. Co. v. Whitman (Ill. Sup.) 40 N. E. 1014.

2. Where a grantor conveys part of a lot by a deed describing it by metes and bounds, and subsequently conveys the balance of the lot to another, describing it as being bounded by the land previously conveyed, the grantee in the first conveyance is limited to the tract described in his deed by metes and bounds, though less than it was the intention of the parties thereto to convey.—[Probett v. Jenkinson (Mich.) 63 N. W. 648.

3. A deed which conveys 134 acres on the north side of a lot of land, described by its number, district, and county, the lot being by statute a square, is sufficiently certain to embrace such a parallelogram as would result from drawing a line across the lot, parallel with its northern boundary, so as to cut off 134 acres.—[Gress Lumber Co. v. Coody (Ga.) 21 S. E. 217.

4. Where a deed describes land as bounded by a certain alley, declared such by ordinance, and the grantee and other grantees of lots thereon build their fences on the line thereof, and use it together with the public, the grant is to the middle

of the alley, though the city did not work the alley as thus located, and afterwards changed its location.—[Bliem v. Daubenspeck (Pa. Sup.) 32 A. 337.

DRAINAGE.

1. 3 How. Ann. St. § 1740a7, limits the jurisdiction of "township" drain commissioners to the drains lying entirely within the township, and provides that the county drain commissioners shall have concurrent jurisdiction with the township commissioners. Id. § 1740a8, provides that, "in case it is proposed to run a part of a drain through an incorporated city, the whole of such drain shall be constructed * * * by the county commissioners, and wherever the word 'township' is used in this act, it shall be construed to mean 'city,' as the case may be." *Held*, that the county commissioners have no jurisdiction to construct a drain lying wholly within a city whose charter gives it jurisdiction over its drainage.—[Mason v. Detroit, G. H. & M. Ry. Co. (Mich.) 62 N. W. 989.

2. The probate court has no power to review and set aside the verdict of a jury finding that a proposed drain is not necessary.—[Palmer v. Willett (Mich.) 62 N. W. 1027.

3. 3 How. Ann. St. §§ 1740f, 1740f3, 1740h, provide that the drainage commissioners shall make a special assessment roll, and file it in the office of the township clerk, who shall, on or before October 1st, make and deliver to the supervisor a certified statement of the taxes to be raised on the respective descriptions of land, and require the supervisor to lay the matters certified before the board of supervisors. *Held*, that the township clerk and township supervisor cannot refuse to perform the duties prescribed by such statute on the ground that, in their opinion, the assessments would be invalid, because of irregularities in the proceedings to lay out the drain. —[Laubach v. O'Meara (Mich.) 64 N. W. 865.

4. In proceedings for the appointment of special commissioners to determine the necessity of a drain and the taking of private property for the same, where the name and residence of a non-resident owner, who refused to release, are known, notice by publication from which said owner's name was left

out is insufficient to give jurisdiction under Pub. Acts 1893, § 7, requiring the citation to be addressed to such owner.—[Campau v. Charbeneau (Mich.) 63 N. W. 435.

5. Under Act 1885, No. 277, c. 6, §§ 6, 7, 14, drainage taxes, when reassessed, are to follow the course of other taxes, and be collected in the same manner; if necessary, by sale for non-payment.—[Bump v. Jepson (Mich.) 64 N. W. 509.

MUNICIPAL CORPORATIONS.

1. A street was opened 66 feet wide, on which a roadway 38 feet wide was filled in 6 feet above an abutting lot. The owner of the lot constructed a stone wall along the curb line of the roadway, to its full height, and a plank sidewalk over the space between the roadway and his lot. Afterwards he sold the lot to plaintiff, excepting the right of way for the street. A contract, under regular proceedings, was afterwards let to pave the roadway 42 feet wide. Notice was given plaintiff to remove the wall, which she refused to do. The contractor, then, under direction of the city, removed the planks, placed them upon plaintiff's lot, covered up the wall, and paved above it. *Held*, that the city was not guilty of conversion.—[Fuller v. City of Grand Rapids (Mich.) 63 N. W. 530.

2. The resolution of a common council, declaring the paving of a street 66 feet wide to be a necessary public improvement, was silent as to the width of the roadway. The estimate of the board of public works, previously made, specified a roadway 38 feet wide, the width of the old roadway. Before the letting of a contract, new plans were filed showing that the roadway was to be 42 feet wide. *Held*, that the change of the width did not vitiate the proceedings.—[Fuller v. City of Grand Rapids (Mich.) 63 N. W. 530.

3. The determination of the question of the benefit to private property in improving a highway is vested in the municipal authorities, and, in the absence of fraud, their determination is final.—[Shimmons v. City of Saginaw (Mich.) 62 N. W. 725.

4. Under Local Acts 1889, No. 455, tit. 6, § 16, providing that proceedings of the common council shall be matters of

record, and shall not fail on account of any technical error unless the party complaining shall show affirmatively that he has been injured thereby, failure to record proof of publication of notice of hearing on assessments is immaterial, where it is shown that such publication was had.—[Shimmons v. City of Saginaw (Mich.) 62 N. W. 725.

RIPARIAN RIGHTS.

1. A deed conveying land extending to the "shore" of an inland lake imports only a land boundary, and not one by the water of such lake, under which riparian rights would arise. —[Axline v. Shaw (Fla.) 17 So. 411.

2. Under the riparian act of December 27, 1856, the operation of which is expressly limited to those "owning lands actually bounded by and extending to low-water mark on such navigable streams," riparian rights do not exist unless there is an actual water boundary to the land in connection with which such rights are claimed.—[Axline v. Shaw (Fla.) 17 So. 411.

3. The land below high-water mark does not necessarily pass to a grantee of the upland as appurtenant to the latter. —[Axline v. Shaw (Fla.) 17 So. 411.

4. A portion of a fractional section bordering on a navigable stream was washed away by the current. An accretion formed from an island in the river, and extended within the boundaries of the section, but did not connect with the new shore line. *Held*, that the owner of the section had no title to any part of the accretion.—[Cox v. Arnold (Mo. Sup.) 31 S. W. 592.

5. Where the government grants lands on the bank of a fresh-water stream, without reservation, in states where the common law prevails, all unsurveyed islands between the middle line of the stream and the bank pass by the grant, and the riparian owner cannot be divested by a subsequent survey and grant of the islands.—[Grand Rapids & I. R. Co. v. Butler, 15 S. Ct. 991.

6. A conveyance of lands on a navigable stream by a description establishing a boundary line coincident with the

line of navigation conveys the grantor's title to the central thread of the stream.—[Lake Shore & M. S. R. R. v. Platt (Ohio Sup.) 41 N. E. 243.

7. Where two irregular pieces of land lie on the north side of a river running southeast, and are separated by a half quarter-section line running north and south, accretions formed by the recession of the river to the south belong to the respective tracts lying due north thereof, and the division line between the two tracts continues to the half quarter-section line extended.—[McCaman v. Stagg (Kan. App.) 43 P. 86.

8. The fact that the meander line of a navigable lake, as established by government surveyors, did not coincide with the shore line of the lake, will not overcome the presumption that the government, in patenting land adjoining the meander line, intended to convey the land lying between such line and the lake.—[Schlosser v. Crookshank (Iowa) 65 N. W. 344; Caldwell v. Jackson, Id.; McNary v. Same, Id.

9. The fact that the number of acres recited in a government patent corresponds with the quantity within the meander line along a navigable lake will not prevent the patentee from claiming the land between the meander line and the shore line. —[Schlosser v. Crookshank (Iowa) 65 N. W. 344; Caldwell v. Jackson, Id.; McNary v. Same, Id.

10. The owners of land adjoining the meander line of a navigable lake, as established by government surveyors, are riparian owners, and entitled to all land lying between such line and the high-water line of the lake, though most of such land is high, and not subject to overflow.—[Schlosser v. Crookshank (Iowa) 65 N. W. 344; Caldwell v. Jackson, Id.; McNary v. Same, Id.

COUNTY SURVEYORS' RECORDS.

VAN DER GROEF v. JONES et al.

(Supreme Court of Michigan. Dec. 30, 1895.)

RECORD OF SURVEYS—ADMISSABILITY—EFFECT—ADVERSE POSSESSION—ESTOPPEL.

Error to circuit court, Kalamazoo county; George M. Buck, Judge.

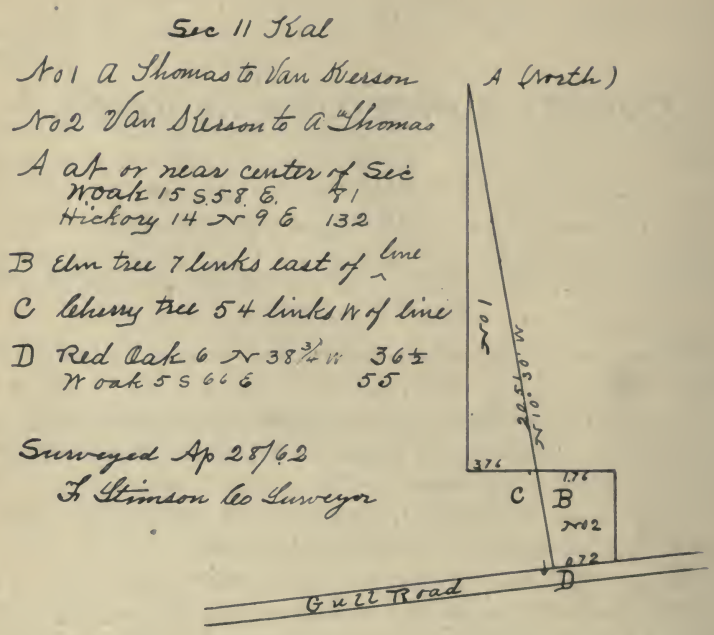
Trespass by Adrian Van Der Groef against John W. Jones and another. There was a judgment for plaintiff, and defendants bring error. Reversed.

H. O. Bliss and Howard & Roos, for appellants. James H. Kinnane and Oscar T. Tuthill, for appellee.

GRANT, J. The dispute in this case arises over the boundary line between the lands of the plaintiff and the defendant Jones, Knowles being his tenant. Their lands are situated in the N. W. ¼ of the N. E. ¼ of section 11, in the township of Kalamazoo. Plaintiff made two claims: (1) That the true boundary line was outside the place where the alleged trespass was committed. (2) If it were not the true boundary line, he had obtained title by adverse possession.

1. Both parties introduced surveys made by competent surveyors. The principal errors arise over the admission of and the effect to be given to a record of a survey found upon the surveyor's record of Kalamazoo county, made April 28, 1862, by the then county surveyor. A copy of this record was introduced, over the objection and exception of the defendants. It will be found on following page.

As to the effect of this survey, the learned circuit judge instructed the jury as follows: "The jury is instructed that the United States government, in its original survey, fixed the section corners and quarter posts. The division of the section was afterwards done by surveyors, and points established thereon,


Sec 11 Kal
No 1 A Thomas to Van Kerson
No 2 Van Kerson to A Thomas
A at or near center of Sec
W oak 15 S 58 E 81
Hickory 14 N 96 132
B Elm tree 7 links east of line
C Chestnut tree 54 links W of line
D Red Oak 6 N 38¾ W 36½
W oak 5 S 66 E 55
Surveyed Ap 28/62
F Stimson Co Surveyor
A (North)
100
N 0° 30' W 220.1
376
176
C
B
No 2
272
D
Gull Road

from the original corners and quarter posts thereon, and if so done by a county surveyor, and a record made by him thereof in a book kept by him for that purpose, as required by law, then such recorded survey is evidence of itself, and the points indicated there must be taken as true." After instructing the jury, as requested by the defendants, that the survey made by the county surveyor is of no greater weight as evidence than those of any other surveyors of equal ability and skill, the judge said: "This is true, gentlemen, but it needs this modification, as I have already practically instructed you, whenever a county surveyor is called upon to make what is practically a resurvey. The survey originally made by the county surveyor, having been recorded in the book, must be taken as true and correct, whether it be exactly done according to his mathematical skill, or the mathematical skill of his profession. * * * It appears by the undisputed evidence that in the year 1862 Fancher Stimson, then the county surveyor of this county,

made a survey of part of section eleven, and that by such survey he fixed and established a point he called a 'center' of said section eleven, and noted the bearings of certain witness trees, as required by law. The center of the section, being thus fixed and established by the proper authority, could not afterwards be changed, whether the center thus established was the true geographical center or not; and any subsequent survey should be for the purpose of ascertaining where the original location of this central point was, and not to determine where it ought to have been." Other language of similar import was used. The practical result of this ruling was the establishment of the line as claimed by the plaintiff.

We think the learned circuit judge was in error in admitting this survey in evidence, and in his instruction as to the effect to be given to it, if it had been such a record as the law makes admissible in evidence. The statute upon which the plaintiff relies is as follows: "The certificate of the surveyor, or his deputy, of any survey made by him of any lands in the county, shall be presumptive evidence of the facts therein contained, unless such surveyor or deputy shall be interested therein." How. Ann. St. § 616. Section 619 provides what the record in the surveyor's book shall contain, and, unless those provisions are complied with, the record is inadmissible for any purpose. Smith v. Rich, 37 Mich. 549. The provisions of section 619 will there be found stated in full. The record of surveys in that case was held inadmissible, because, among other reasons, neither of them appeared to be a survey of any piece of land, nor did either show for whom the survey was made, or the variation of the magnetic needle from the true meridian. The record of the survey in this case does not show for whom it was made, nor the variation of the magnetic needle from the true meridian. It contains no statement that point A is the center of the section. It simply says "at or near the center of the section." This expression cannot be regarded as a permanent establishment of the center of the section, binding upon those who are not interested or parties to the making of that survey. It was held in Hess v. Meyer, 73 Mich. 259, 41 N. W. 422, that a law providing that a record

made and entered by the surveyor upon the surveyor's book shall be received as evidence in all the courts of this state did not make a prima facie case, and it was error to so instruct the jury. The record of a survey which complies with the statute now under consideration is undoubtedly presumptive evidence of the facts therein found, and casts the burden of proof upon the opposing party to produce evidence to rebut the presumption. Whenever, however, other surveys are introduced made by competent surveyors, such survey is of no more binding force than any other, where parties have not acquiesced in it.

2. We think there was ample evidence for the consideration of the jury upon the question of adverse possession. The principles of law in such cases were correctly given, and there was a fair dispute upon the facts. It is, however, claimed on behalf of the defendant Jones that the plaintiff rented some of the disputed land from him, and that this broke the continuity of possession necessary to obtain title, and estopped him to assert such adverse possession. This also was disputed, and upon this point the court clearly instructed the jury that, if they found the fact as claimed by the defendants, the plaintiff had obtained no title by adverse possession. When the defendants removed the fence from the land as claimed by plaintiff, and where it had existed many years, and built it upon the line as claimed by them, the plaintiff said he would have a resurvey to determine where the real line was, and would not abide by the survey which they had caused to be made. Such statement did not estop him from setting up, upon this trial, adverse possession. It was not a conclusive assertion that he did not rely upon it. The judgment must be reversed, and a new trial ordered.

McGrath, C. J., did not sit. The other justices concurred.

MICHIGAN ENGINEERING SOCIETY.

THE SAGINAW CONVENTION AND BUSINESS MEETING.

The 17th Annual Meeting of the Michigan State Engineering Society was held in the parlors of the Vincent House, at the city of Saginaw, January 7, 8 and 9, 1896.

The Convention was called to order, Tuesday afternoon at two o'clock, by the President, Mr. Wells, who introduced to the Society Mr. William B. Mershon, Mayor of the city of Saginaw. Mr. Mershon welcomed the members to the city in the following words:

MR. CHAIRMAN, AND GENTLEMEN:

It struck me, as I was sitting here, that in view of the reputation Saginaw has had for being a loud and boisterous city, it would be a relief to welcome as quiet and orderly a body of men as you all have appeared to be for the last four or five minutes.

I attended a meeting of lumbermen in Buffalo a few months ago, and Mayor Jewett, of that city, welcomed the gathering and extended to them the freedom of the city, and I at that time, thought he did it very nicely, and I wished that I were gifted with his power of expression, that I might welcome such organizations to Saginaw whenever it should be my good fortune to do so. He dwelt upon the good points and many advantages of the city in which he was mayor, and when he had finished, I think every man in the room had made up his mind that Buffalo was about the best city in the universe.

Now, I cannot, I know, create that impression in regard to Saginaw, as much as I would like, but I do think our city has a good many good points, and the engineering department of the city is to blame for many of them. We are dependent upon our city engineer, as you know, for our good streets—which unfortunately are covered with snow at the present time, so you cannot judge of them.

We are also blessed with what is, I think, the best sewerage system of any city of its size in the Union, and Mr. Roberts and his predecessor, Mr. Canfield, have both had a great deal to do with that, and I can assure you, gentlemen, that the sewage always flows toward the lower end of the outlet. It is a great success in that respect.

Another system recently introduced here is that of tile drains vs. open ditches in our streets, and we have had to fight that tooth and nail for many years, but at last we are successful, in a measure, and I do not think the people would for a moment go back to the old system of open ditches.

The water-works system is complete, considering the source of supply. It affords splendid fire protection, and take it as a whole, I think Saginaw is a city of which I can be proud to be mayor, and that being the case, it is with good grace that I welcome you, gentlemen, to our city, and I trust that your meeting here will abound with the success you anticipate.

I thank you, Mr. President and Gentlemen, for the honor of extending to you this welcome, and I hope that your stay will be long, and I can assure you that your welcome will not be worn out.

(Applause.)

The President.—Permit me to thank you in behalf of the Michigan Engineering Society for the warm, hearty welcome which you have given us.

We meet once each year, in various parts of the state, to discuss topics of interest, not only to the members of the Society, but to the public generally.

From these meetings the profession receives a great amount of good, but the benefit which the public derives from them is immeasurably greater, for by our published proceedings, — scientific investigation and engineering experience, covering a broad field of public works and improvements, — are laid at the very door of every community.

We publish papers and discussions showing where failure and success have been met, indicating to the public how large expenditures of money and annoyance can be saved. We

discuss methods of constructing and maintaining public works with the view of protecting the lives and preserving the health of the people.

As we are bound by no narrow code of ethics, as closed doors and secrecy have no part in our deliberations, as we use only the language which the people understand, and as it is the single aim and purpose of this society to convert the bounties and forces of nature to the use of man, you and the public are most cordially invited to attend all of our meetings.

We especially invite the members of the city government.

I see that the secretary has put me down for an address to the Society and in obedience to his wish, I respond.

(Applause.)

GENTLEMEN:

In opening this meeting I would be ungrateful if I did not express to you my appreciation of the honor you have done me by electing me president of this society. It is, indeed, an honor to be called to preside over a body of men, though numerically small, yet men recognized and honored in the communities in which they live not only for their good citizenship, but for their superior intelligence, learning and industry.

I shall endeavor to show my appreciation of the honor by advancing the interests of the society whenever I have an opportunity, and in carrying out your instructions.

There are some matters of interest to the society to which I wish to call your attention.

The individual efforts of every member is needed to reach that mutual good, which was the prime idea that brought this organization into existence. Every member should contribute his part by preparing papers or discussions to papers read at a previous meeting, securing new and desirable members and increasing our revenues by obtaining advertising patronage for our Annual.

Requests for papers have been promptly responded to by quite a few of the members, but in many instances no responses have been received, while others have declined for a variety of reasons.

Now, we can hardly expect this society to run automatically by an annual winding up by the secretary. I would like to emphasize the recommendation made by Mr. Geo. E. Steele when president, that members send in short descriptions of new methods employed, of new experiences met, etc., without waiting for an invitation from the secretary, and give him notice of it so he can put it in the program, making it bristle with interest.

It is not necessary to write against space,—a half page description of an interesting experience may be just the thing to help out someone.

No two of us have had the same conditions to work under, so each one of us must know something that the others do not, and I wish to impress it that we are entitled *to know* it.

Modesty seems to be a great draw back in getting some members to contribute. Perhaps this can be overcome if we get out some papers in the form of committee reports, so that those who are bashful can hide it more by working with a committee than if preparing separate papers. I believe this matter of taking up subjects for committee reports is deserving of special attention by the society.

There are quite a number of good engineers in the state who are not members and we ought to get them into the society, and every member should constitute himself into a committee of one to urge all engineers who are not on our roll to join.

Our published proceedings cost more money than is possible to raise from membership dues.

We are entitled to a share of the advertising patronage of manufacturers and dealers in supplies which enter into the construction of public works, and we can get it if we ask for it. One man cannot get it all, but if each member would solicit a page of advertising matter from each firm with whom he deals, we will all be surprised at the volume of our revenue and improvement we can make in our already carefully edited Annual.

It is a matter of regret that the rule of the Michigan Railway Association, requiring an attendance of one hundred members to a meeting, has prevented us from securing reduced

railroad fares. We tried hard to get the railroads to grant us a concession in the number of members in attendance to secure the rates, but they declined to do so and in addition to the requirement of asking for one hundred attendance, they asked us five dollars a day for the services of one of their employees to attend the meeting to sign certificates.

It would hardly be within the province of this address to review the changing conditions and lack of employment with which engineers have had to contend the last few years. There is one line of work which will soon engage the services of as many engineers as railroad construction did a few years ago. Most everyone gives the matter some attention. Every one who rides a bicycle has given the subject extra thought. Doubtless horses have given it more thought than their masters. Even the farmers who are far enough advanced to ride wheels think well of it. A small minority of them have long ago figured out the economy of *good roads*. The signs of the times are that good roads are a thing of the near future. In some communities now, there are enough bicyclers who can elect their candidate for highway commissioner. In 1895 demands for bicycles were greater than the manufacturers could supply. In 1896 there will be nearly twice as many factories at work as there were in 1895, besides many old factories have doubled or greatly increased their facilities. This indicates that the annual plowing given highways and the fossilized path-masters will soon be a thing of the past, and scientific road building the order of the day under the direction of intelligent commissioners, and supervision of competent engineers.

The following letter was presented by Mr. Roberts:

R. W. Roberts, Esq., City:

Dear Sir:—I hereby extend, through you, to the Michigan Engineering Society, free transportation over all our lines, during the time of their attendance at their annual convention to be held in our city, next week, and cordially invite the Society to visit our power plant, shops, etc., on any day they may designate.

Members will please present or show their badges to the conductors, which will be sufficient for their transportation.

Very respectfully,

W. J. HART, Gen. Mgr.

On motion of F. Hodgman, the invitation was accepted and the thanks of the Society voted to the company for the courtesy.

The following committees were appointed:

On President's Address—Messrs. Rogers, Sears and Doane.

On Exhibits—Messrs. Hubbell, Rogers and Granville.

On Mr. Barrington's Paper—Messrs. Hubbell, Treadwell and Skeels.

To Secure Advertising for the Annual—The President and Secretary, and Messrs. Sears, Masson, Hubbell, Rogers, Granville, Roberts, Taft, Douglass, Muenscher, Riggs, McVean, G. M. Brown, Ames, G. S. Williams, Dunbar, C. Holmes, Hillyer, and Walker.

On remission of dues in certain cases—Messrs. Appleton, Muenscher, Skeels and Granville.

On donation of reports to certain libraries—Messrs. Treadwell, Vedder and Ames.

It was voted to pay the secretary $125 for services in 1895.

It was voted to submit to the Society by letter ballot an amendment to Article III of the constitution, striking out therefrom the date of the annual convention, leaving the date to be determined by the board of directors. Such amendment was submitted as directed on the first Monday in March.

The following nominations were made for officers for the ensuing year:

For President—Geo. L. Wells.

For Vice President—Frank F. Rogers, G. M. Ames, H. E. Riggs.

For Secretary and Treasurer—F. Hodgman.

For Directors—Wm. Appleton, G. S. Williams, Wm. B. Sears, M. Walker, H. K. Vedder, Dorr Skeels and C. E. Greene.

It was voted that the president appoint a committee of three, to be assisted by Mr. T. P. Whittier, to prepare a model city ordinance for regulating the franchises of electric street

railways, and report at the next convention, or through the next Annual if practicable. The president took time to consider and now announces as such committee: R. W. Roberts, chairman; J. J. Granville and Wm. Appleton.

The local arrangements for the convention were all that could be desired and the Society received a royal welcome from the citizens of Saginaw and the local members. Wednesday afternoon was spent in visiting the works of the Lufkin Rule Company, the Saginaw Brick Company and other points of interest in the vicinity. Wednesday evening, after business was transacted, the doors of the dining room were thrown open and a magnificent banquet was spread and served the Society. It came as a surprise from the local committee, and was highly appreciated.

The remainder of the evening was spent in social enjoyment, stories and music. In appreciation of the various courtesies extended the Society, votes of thanks were extended to the Street Railway Company, the Lufkin Rule Company, the Saginaw Brick Company, the local committee and the proprietor of Hotel Vincent. At the close of the convention the following reports of committees were presented and acted on.

The committee on Questions in Land Surveying made the following report, which was adopted:

MR. PRESIDENT:

Your committee would respectfully report that the following question has been submitted to them: "A section is surveyed and subdivided on application of the resident land owners. Part of the section is non-resident. Do the non-residents receive any benefit from the lines and who is to pay for the same."

We are of the opinion that if the person making the subdivision was County Surveyor at the time of subdivision, that the statute under which he is officiating as County Surveyor provides for his getting his pay, when doing work on proper petition. If the subdivision was properly done, non-residents get equal benefits with residents.

DORR SKEELS,
JOHN RANDALL,
GEO. W. DOANE,
} Committee.

The committee to whom was referred the request of the Grand Rapids Historical Society for a set of our Annuals, and Mr. June's proposition to place such sets in libraries in different parts of the state, reported favoring such action. The report was accepted and the committee discharged. After some discussion, it was voted to place the whole matter in the hands of the secretary for further action, in his discretion. Accordingly the secretary has had six full sets of the Annual bound and has furnished one set to the Grand Rapids Historical Society, one to the Kalamazoo Public Library and one to the Hoyt Public Library in Saginaw. No other applications have been received up to the time of printing this report.

Last year's committee to whom was referred the question as to the *advisability of joining the Association of Engineering Societies* reported adversely. The report was adopted and the committee discharged.

The committee on Mr. Barrington's paper reported it to be a valuable paper in lines similar to those of Mr. Duncan's, read at this meeting. The report was accepted and committee discharged. This paper, together with a number of others which there was not time to read and discuss at the convention, was referred to the secretary for publication in the Annual.

The secretary stated that the papers presented would make the largest Annual in the history of the Society and would be correspondingly expensive to publish. It was a question of dollars and cents. If sufficient advertising patronage could be secured to warrant the expense, all would be published, otherwise something must be omitted.

The committee on the question of remitting dues in certain cases reported in favor of leaving the whole matter in the hands of the board of directors to remit dues in worthy cases, without publicity. The report was adopted and the committee discharged.

The committee on exhibits reported as follows:

Your committee on exhibits beg leave to make the following report:

The tape exhibit of the Lufkin Rule Company is very complete, containing seven varieties of tapes. There are steel tapes in open reels, steel tapes in nickel plated steel cases. These last are of American steel, and very cheap but good, the graduations being the same as on more expensive makes. Steel tapes in the leather cases are made of French steel. They are all made in lengths from 25 feet to 100 feet, graduated either in feet, inches and sixteenths, 10ths and 100ths, or in centimeters. We are especially pleased with the narrow detachable tape, but think we would prefer the open reels to closed cases on account of the liability of rusting, however, we know that closed cases are almost a necessity on pocket tapes. The metallic tape shown is good for many purposes. We make special mention of the novel and improved handles which are a special feature of the Lufkin tapes.

The Bay Port Quarry exhibit contains samples of crushed stone, building stone and stone paving blocks. The Bay Port rock is very tough stone and is said to have a crushing strength greater than granite.

The samples of vitrified paving brick from the Saginaw Clay Manufacturing Company have the appearance of being as good as any paving brick in the market.

The Michigan Pipe Company, of Bay City, exhibit a steam pipe casing—with 4-inch shell, tin lined. Also a creosoted railroad tie, and samples of wood conduit for electric wires treated in the same manner. Also one length of Wyckoff water pipe, which is largely used in Michigan and various parts of the country in water works plants. It possesses the advantages of not rusting and being unaffected by acids which makes it adapted for use in mines, pulp and fibre mills and chemical works. It is banded with a heavy steel band, wrapped spirally from end to end, which band is put on with a machine, insuring good contact. As the wood is a nonconductor of heat, it resists the action of the frost well. These qualities make it well adapted for water works and general purposes.

The National Cycle Mfg. Co. exhibit a bicycle which is neat in design and finish, and has the new features of the 1896

wheel, which are narrow tread and larger tubes—weight 23 pounds. It appears to be a high grade wheel of much merit.

Mr. Whittier exhibits a roller bearing sulky wheel which appears to be much easier and smoother running than a ball bearing wheel which is shown with it.

F. F. ROGERS,
JOHN J. GRANVILLE.

Report accepted and committee discharged.

The committee on president's address reported as follows:

GENTLEMEN OF MICHIGAN ENGINEERING SOCIETY:

Your committee appointed to report on the advisability of our Society appointing special committees to make extended study of various topics of interest to our members, most heartily approve the suggestion of our president and have named the committees to work on the following topics:

1. Committee on Forestry, to study the climatic effect of the removal of forests and to report plans for preserving the same—F. E. Skeels, Grand Rapids; J. J. Hubbell, Manistee; John Randall, Chas. Holmes, Saginaw, E. S.; Henry Melchers, Jr., Saginaw, E. S

2. Committee on Materials for Street Paving; their use and utility, Macadam and subdrainage to be included—H. A. Coller, Grand Rapids; Wm. Appleton, Lansing; R. W. Roberts, Saginaw, E. S.

3. Committee on Relation of Water Supply and Sewerage to Public Health—G S. Williams, Detroit; H. E. Riggs, Toledo, O.; F. F. Rogers, Port Huron.

The committee on Cements being already appointed is not mentioned.

F. F. ROGERS,
WM. B. SEARS,
GEO. W. DOANE.

The report of the committee was adopted.

The annual report of the secretary to the convention was read and approved.

SECRETARY'S REPORT TO THE CONVENTION.

The board of directors of the Michigan Engineering Society met at Hotel Downey, in Lansing, Wednesday, September 18, 1895, at 9 A. M. There were present Directors Greene and Skeels, and Secretary Hodgman and Members Appleton and Sears. Ballots for officers were canvassed and the following found and declared elected:

President—George L. Wells.

Vice President—Frank F. Rogers.

Secretary–Treasurer—F. Hodgman.

Directors—Wm. B. Sears, Dorr Skeels, Wm. Appleton.

The annual reports of the secretary and treasurer were read and approved. They are as follows:

SECRETARY'S ANNUAL REPORT.

To the Board of Directors of the Michigan Engineering Society:

I would respectfully report the following business transacted by me for the Society since the last annual convention:

Immediately after the convention I set about securing advertising patronage for the Annual report, and also got bids from various firms for its publication. It was late before enough funds were in sight to warrant awarding the contract for printing, which was then let to the lowest bidder, Robert Smith & Co., of Lansing. Owing to the desire to keep the publication of the Annual within our known means for payment, some matter was omitted which would otherwise have appeared. Prof. Greene withdrew his paper which was published in the Technic, and will thus reach the members of the Society. Mr. Watkins' lengthy paper on riparian rights was also withdrawn by the author. Mr. Steele's paper on the provisions of the general acts for the incorporation of villages and

cities was received too late for discussion in the convention, and as the acts which it was desired to amend had passed the legislature before the Annual was fairly begun, the paper was omitted. Mr. Barrington's paper on American bridge practice which was not read in the convention for want of time, was held over. It will be ready for use at the next convention if desired, and for publication later. As the printing proceeded somewhat slowly, the secretary continued to solicit ads. until the last moment and enough were secured so that it was not necessary to omit any other papers. 1,500 copies were printed.

Arrangements have been made for the usual exchanges, although there is doubt in regard to the Indiana exchange. That Society published no report in 1894. Early this year I learned from Mr. O'Brien, their new secretary, that the 1894 and 1895 reports would be published together in good season. Since then I have had no reply to my letter to him. I had our reports for that Society sent direct to him from the printers and was recently notified by Smith & Co. that he refused to receive them. I have received the Technic and Technograph, and also the Iowa and Connecticut reports but no others

Ballots for members were sent out at the proper time and the result of the ballot was announced in the Annual. Two members, Mr. F. H. Williams, of Allegan, and F. S. Bigler, of Detroit, have applied for withdrawal. Mr. Bigler has paid up his dues to date of the application and is entitled to honorably withdraw from the Society. Mr. Williams has not paid up. Mr. Sowter, who applied last year for withdrawal, has not paid up his dues. In the case of S. N. Beden, who was reported last year for two years' non-payment of dues and whose case was then deferred, the secretary learns that he still lives in extremely poor health from which he will probably not recover. I would suggest that it might be appropriate to enact a bylaw under which the directors may have the power to transfer aged members or those who are poor and in ill health from the active to honorary membership, and exempt them from the further payment of dues or assessments.

At the last annual meeting of the board of directors the secretary was directed to proceed to collect from R. C. Pope,

of Chicago, the amount due from him for advertising. The papers were placed in the hands of Martindale & Co., of that city, who, after a liberal amount of dunning, returned the papers and reported the account as worthless.

Ballots for officers were sent out to the members August 15th; also, notifications were sent to all those in arrears for dues. The ballots received are herewith returned to be canvassed.

F. HODGMAN, Secretary.

TREASURER'S REPORT.

During the past fiscal year I have received and disbursed for the Society the following sums:

RECEIPTS.

On hand Oct. 10, 1894	$105.72	
Received for membership fees	23.00	
" for dues	301.45	
" for advertising	105.00	
" from sale of Reports	28.00	$564.27

EXPENDITURES.

Paid expenses of Board of Directors and Secretary	$ 36 79	
" Secretary as voted by Society	100.00	
" Prof. Greene for 1883 reports	24.00	
" H. E. Speir, stenographer	58.20	
" for Am. Digest and Law Reporter	4.25	
" " miscellaneous printing, plates, Annual, circulars, etc.	118.00	
" for postage and envelopes	29.75	
" " express and freight	6.02	
" " copyright	1.00	$378.01
Balance on hand Sept. 18, 1895		186.26
		$564.27

There is due to Robert Smith & Co. for printing the Annuals, ballots, circulars, etc., $152.11.

There is due the Society from advertisers	$115.50		
" " " for Reports sold	24.00		
" " " from members, '95 dues	88.00		
" " " " " '94–'95 "	40.00	$267.50	

Doubtless a considerable portion of this sum will never be paid. So far as cash is concerned, the condition of the Society's finances may be summed up as follows:

ASSETS.

Cash on hand	$186.26	
Due from advertising	115.50	
" " customers for Reports	24.00	
" " members	128.00	$453.78

LIABILITIES.

Bills payable, R. Smith & Co.	152.11
	$301.65

The Society has on hand a large quantity of Reports, books, engineering papers and instruments of very considerable value of which no inventory has ever been made.

F. HODGMAN, Treasurer.

STATE OF MICHIGAN, } ss.
Kalamazoo County, }

Subscribed and sworn to before me, a notary public in and for Kalamazoo county, this 17th day of September, 1895.

WILBUR C. POND, Notary Public.

It was voted to hold the next convention in Saginaw, January 7, 8 and 9, 1896, and the members living in that city were appointed local committee on arrangements. The question of amending the by-laws to provide for remission of dues in certain cases was presented and discussed. The further arrangement for the convention was left in the hands of the newly elected officers. The board then adjourned.

F. HODGMAN, Secretary.

A special meeting of the board of directors was held on January 9th at Hotel Vincent, all the members being present. Applications for withdrawal were received from F. S. Bigler, F. H. Williams, E. W. Redman and F. A. Rice, which applications were granted.

The membership of Wm. R. Coats was annulled for non-payment of dues. Applications for membership were received, approved and classified as follows:

FOR SENIOR MEMBERS.

D. A. Brotherton, city engineer, Escanaba; Geo. F. Martin, city engineer, St. Joseph; C. Mason, engineer and salesman, Detroit; V. V. Newell, mechanical engineer, Agricultural College; Byron E. Parks, mechanical engineer, Grand Rapids; C. C. Pashby, instructor in mathematics and civil engineering, Agricultural College; John Randall, now a junior member; S. S. Reed, county surveyor, Three Rivers; F. B. Slocum, sales manager for H. R. Worthington, Detroit; R. C. Smith, civil engineer and surveyor, F. & P. M. R. R., Saginaw; Thos. P. Whittier, manufacturer, Saginaw.

FOR JUNIOR MEMBER.

P. R. Bush, surveyor and civil Engineer, Saginaw, Mich.

Letter ballots were sent out as required by the by-laws and all the applicants elected to membership.

THE TEREDO NAVALIS.

The following statement, by Mr. E. U. Hunt of the Nicaragua Canal Survey, was received too late to be printed in connection with Mr. Wells' paper on the Artificial Preservation of Timber, for which it was intended:

E. U. Hunt.—In Nicaragua the teredo seemed to be in the San Juan river as far up as Machoca Rapids, eighty miles from Greytown, as the Navigation Company had some lighters at that point which they used for taking coffee over the rapids in the dry season, and in one year they were so badly eaten that they were obliged to take them out and put zinc on their bottoms. In the harbor at (San Juan Del Norte) Greytown the teredo ate the piling under the railroad wharf and docks nearly as bad as they did outside in the sea. The harbor is practically fresh water, owing to the light tide and narrow channel and large amount of water flowing through from the river. The river San Juan and Lake Nicaragua are, I believe, the only fresh waters on the continent in which shark abound, and there are plenty of them there, as I have caught them sixty miles up the river.

ERRATA.

In Mr. Wells' article on Artificial Preservation of Timber, page 300, "profitable profit" should read "probable profit.'

Page 309, "6x6 inches—" should read, "6x6 inches×—."

MICHIGAN ENGINEERS' ANNUAL.

This Annual publication is the organ of the Michigan Engineering Society and contains the papers read before the Society and the discussions thereon.

These Annuals contain more than 200 papers on matters of interest to Surveyors and Civil and Mechanical Engineers, written by practical men of experience who know thoroughly what they are writing and talking about. Some of the subjects treated are Land Surveys, Railway Surveys, Construction and Maintenance, Easement Curves, Photographic Surveying, Hydrographic Surveying, Cemetery Surveying—plats and records, Village Plats, Map Drawing, Highway Location and Construction, Bridge work, Waterworks, Sewerage, Drainage Engineering, Irrigation, and an extensive digest of legal decisions of special interest to Land Surveyors and Civil Engineers.

This large amount of valuable matter, constituting an engineering education of itself, can be had in no other place or form. The Society offers these annuals for sale at the following prices:

For the years 1880, 1881, 1882 and 1884.....50 cts. each.
For 1885.....75 cts. "
For 1891, 1892, 1893, 1894 and 1895.....$1.00 each.
For 1896. ..... 1.25 "

For the intermediate years the Society has but very few copies left and these will only be sold in full sets. Price of the full sets, 1880 to 1896 inclusive, $12. For sale by

F. HODGMAN, Sec'y Mich. Eng. Society, Climax, Mich.

LIST OF MEMBERS, 1896.

SENIOR MEMBERS.

Allen, Jerome, Surveyor, Milan, Monroe Co., Mich.

Appleton, William, Civil Eng., Lansing, Ingham Co., Mich.

Ames, Geo. M., Asst. City Eng., Grand Rapids, Kent Co , Mich.

Bailey, M. H., Surveyor, Dimondale, Eaton Co., Mich.

Bradt, J. C., Surveyor, Marcellus, Cass Co., Mich.

Bradt, E. F., Mining Engineer, Ispheming, Marquette Co., Mich.

Barrington, Edward, Civil Engineer, Columbia Bdg., New York City.

Barthel, Adolph, Mechanical Expert and Solicitor of Patents, Detroit, Mich.

Beckmann, L., Manufacturer Surveying Instruments, Toledo, Ohio.

Beden, Seth N., Surveyor and Civil Engineer, Pine Run, Genesee Co., Mich.

Blair, James, City Engineer, Adrian, Lenawee Co., Mich.

Bean, Henry F., Civil Engineer, Jackson, Jackson Co., Mich.

Brown, F. H., Surveyor, Sault Ste. Marie, Chippewa Co., Mich.

Brown, Geo. M., Superintendent of Roadway and Structures, F. & P. M. R'y Saginaw, East Side, Saginaw Co., Mich.

Bement, Clarence E., Manufacturer, Lansing, Ingham Co., Mich.

Bristol, Geo. F., Civil Engineer, Grand Rapids, Kent Co., Mich.

Brotherton, D. A., Civil Engineer, Escanaba, Mich.

Campau, Thomas, Surveyor, Detroit, Wayne Co., Mich.

Cooley, M. E., Prof. Mech. Eng., Univ. of Mich., Ann Arbor, Washtenaw Co., Mich.

Carpenter, L G., Prof. Eng., State Ag'l College, Fort Collins, Col.

Cavis, C. H. V., Consulting Engineer D. S. S. & A. R'y, Marquette, Marquette Co., Mich.

Cornwell, Clark, Paper Manufacturer, Ypsilanti, Washtenaw Co., Mich.

Callard, J. L., Civil Eng., Sault Ste. Marie, Chippewa Co., Mich.

Cummings, Geo. P., Surveyor and Civil Engineer, Marquette, Marquette Co., Mich.

Cummings, Chas., Surveyor and Civil Engineer, Marquette, Marquette Co., Mich.

Cummings, W. L., Civil Engineer, Grand Rapids, Kent Co., Mich.

Courtright, P. A., Surveyor, Duck Lake, Calhoun Co., Mich.

Davis, L. M., Principal Asst. Eng. Minn., St. P. & S. Ste. M. R'y, Minneapolis, Minn.

Davis, J. B., Asst. Prof. Civil Engineering, Univ. of Mich., Ann Arbor, Washtenaw Co., Mich.

Dennis, E., Mechanical Engineer and Manufacturer, Jackson, Jackson Co., Mich.

Dean, Seth, Civil Engineer, County Surveyor, Glenwood, Iowa.

Denison, C. S., Prof. of Drawing, University of Mich., Ann Arbor, Washtenaw Co., Mich.

Drew, Albert L., Surveyor and Real Estate, Three Oaks, Berrien Co., Mich.

Dunbar, E. L., Chief Engineer and Supt. of Water Works, Bay City, Bay Co., Mich.

Doane, Geo. W., Surveyor, Duffield, Mich.

Dewey, F. S., Civil Engineer and Contractor Alpena, Mich.

Douglass, Benj., Bridge Engineer, M. C. R. R., Detroit, Wayne Co., Mich.

Eaton, Albert, Surveyor and Civil Engineer, Glenn, Allegan Co., Mich.

Elder, W. D., Civil Engineer, Kalamazoo, Kalamazoo Co., Mich.

French, E., Civil Engineer, Battle Creek, Calhoun Co., Mich.

Fargo, Wm. G., Surveyor and Civil Engineer, Jackson, Mich.

Gardner, Albro, Civil Engineer, Seattle, Washington.

Goodale, O. C., Surveyor, Cheyenne, Wyoming.

Granville, J. J., Civil Engineer and Contractor, East Saginaw, Saginaw Co., Mich.

Greene, C. E., Prof. Civil Engineering, Univ. of Mich., Ann Arbor, Washtenaw Co., Mich.

Harris, J. W., Civil Engineer, Contractor and Manufacturer, Baraboo, Wis.

Harrod, J. W., Surveyor, Ithaca, Gratiot Co., Mich.

Hayes, Eli L., Surveyor and Map Publisher; Buffalo City, Arkansas.

Hemingway, L., Surveyor and Civil Engineer, Benton Harbor, Berrien Co., Mich.

Hodgman, F., Author and Publisher of Manual of Land Surveying and Surveyor's Field Book, Climax, Kalamazoo Co., Mich.

Holmes, Charles, Surveyor and Civil Engineer, 501 S. Park St., Saginaw, Saginaw Co., Mich.

Holmes, J. W., Manufacturer Surveying Instruments, Batavia, N. Y.

Hubbell, J. J., Chief Eng. M. & N. E. R. R., Manistee, Mich.

Hunt, E. U., Civil Engineer, Battle Creek, Calhoun Co., Mich.

Hillyer, V. Sebring, Mechanical Engineer, Grand Rapids, Kent Co., Mich.

Jarvis, Samuel E., Mech. Eng., Lansing, Ingham Co., Mich.

Jopling, Jas. E., Civil and Mining Engineer, Marquette, Marquette Co., Mich.

June, L. W., Surveyor and City Engineer. Big Rapids, Mecosta Co., Mich.

Kirby, Frank E., Engineer, Detroit, Wayne Co., Mich.

La Rue, Benj. F., Civil Engineer, Scranton, Pa.

Masson, Geo., Ch. Eng. of all G'd Trunk R'y Lines West of Detroit R., Detroit, Wayne Co., Mich.

McLoughlin, John, Civil Engineer, Surveyor and Paving Contractor, room 5, Hall Block, Detroit, Wayne Co., Mich.

McLeod, D. A., City Engineer, Manistee, Manistee Co., Mich.

McVean, J. J., Ch. Eng. C. & W. M. and D. L. & N. R'ys, Grand Rapids, Kent Co., Mich.

Mills, Frank P., Agent Cleveland Iron Mining Co., Ishpeming, Marquette Co., Mich.

Mitchell, C. E., Civil Engineer and Contractor, Ludington, Mason Co., Mich.

Mitchell, J. A., Civil Engineer and Contractor, Ludington, Mason Co., Mich.

Morley, Fred, Civil Engineer, Instructor in Dept. of Civil Engineering, Purdue Univ., LaFayette, Ind.

Muehle, B. H., U. S. Assistant Engineer, 34 Congress St., west, Detroit, Wayne Co., Mich.

Muenscher, E. W., Civil Eng., Manistee, Manistee Co., Mich.

Mark, Geo. A., Surveyor, Hillsdale, Hillsdale Co., Mich.

Meighan, Jno. F., Surveyor and Civil Eng., South Bend, Ind.

Mullett, John H., Surveyor, Williamston, Ingham Co., Mich.

Marhoff, A. L., Surveyor and Civil Engineer, Battle Creek, Calhoun Co., Mich.

Melcher, Henry, Civil Engineer, Saginaw, E. S., Saginaw Co., Mich.

Mason, C., Engineer and Salesman Pumping Machinery, Detroit, Mich.

Martin, Geo. F., City Engineer, St. Joseph, Berrien Co., Mich.

Nellist, Jno. F., Surveyor and Civil Engineer, Grand Rapids, Mich.

Newell, V. V., Mechanical Engineer, Foreman of Machine Shops, Agricultural College, Mich.

Pashby, C. C., Instructor in Dept. of Math. and Civ. Eng., Agricultural College, Mich.

Parks, Byron E., Mechanical Engineer, Grand Rapids, Kent Co., Mich.

Pearsons, H. C., Civil Engineer and Ship Builder, Ferrysburg, Ottawa Co, Mich.

Pettee, W. H., Prof. Mining Engineering, Univ. of Mich., 52 Thompson St., Ann Arbor, Washtenaw Co., Mich.

Pierson, Geo. S., Civil Engineer and Contractor, Kalamazoo, Kalamazoo Co., Mich.

Porter, H. H., Hydraulic Engineer, Dowagiac, Mich.

Reed, A. L., Civil Engineer, Whittier, Cal.

Reed, S. S., County Surveyor, Three Rivers, St. Joseph Co., Mich.

Randall, John, County Surveyor and Supt. Water Works, Mio, Mich.

Ripley, Joseph, U. S. Asst. Engineer, St. Mary's R. Imp., Sault Ste. Marie, Chippewa Co., Mich.

Rogers, Frank F., Civil Engineer, Port Huron, Mich.

Russel, Walter S., Vice President Russel Wheel and Foundry Co., Detroit, Wayne Co., Mich.

Rothwell, H. G., Civil Engineer, L'Anse, Mich.

Roberts, R. W., Civil Eng., Saginaw, E. S., Saginaw Co., Mich.

Rumsey, Jas. L., Civil Engineer, Grand Rapids, Mich.

Riggs, H. E., Civil Engineer, Toledo, Ohio.

Redman, C. H., Asst. to City Engineer, Grand Rapids, Mich.

Root, O. J., Mechanical Engineer, Lansing, Mich.

Shenehon, Frank C., Civil Engineer, Sault Ste. Marie, Chippewa Co., Mich.

Sears, Wm. B., Ch. Eng. F. & P. M. R'y, Saginaw, East Side, Saginaw Co., Mich.

Skeels, Dorr, Surveyor and Civil Engineer, Grand Rapids, Kent Co., Mich.

Skeels, F. E., Surveyor and Civil Engineer, Grand Rapids, Kent Co., Mich.

Steele, Geo. E., Surveyor and real estate dealer, Traverse City, Grand Traverse Co., Mich.

Strong, E., Surveyor and farmer, Kalamazoo, Kalamazoo Co., Mich.

Sellers, Ernest O., Civil Engineer and insurance, Lansing, Mich.

Slocum, F. B., Sales Mgr. for H. R. Worthington, Detroit, Mich.

Smith, R. C., Civil Engineer and Surveyor, F. & P. M. R. R., Saginaw, E. S., Mich.

Taylor, Clarence G., Supt. of Shops, Dept. of Mech. Eng., Univ. of Mich., Ann Arbor, Washtenaw Co., Mich.

Teed, A. J., Surveyor and Civil Engineer, Cadillac, Wexford Co., Mich.

Thompson, H. C., Civil Engineer, West Bay City, Bay Co., Mich.

Todd O. H., Surveyor and mint raiser, Fairfax, St. Joseph Co., Mich.

Treadwell, E., Civil Eng., East Saginaw, Saginaw Co., Mich.

Tuthill, Job, Asst. Eng., D. L. & R. R'y, care of Ch. Eng. office, Grand Rapids, Kent Co., Mich.

Thayer, H. L., Civil Engineer, Lansing, Mich.

Taft, M. C., City Engineer, Kalamazoo, Mich.

Tittman, Fred, Civil Engineer, ———, Austria.

Vedder, H. K., Prof. of Civil Engineering, Agricultural College, Mich.

Vincent, Wm., Surveyor, Manistee, Manistee Co., Mich.

Watkins, John J., Civil Eng. and Surveyor, Guthrie, Oklahoma.

Wells, Geo. L., Civil Eng. and Contractor, Grand Rapids, Mich.

Wells, M. N., Res. Eng., A. T. & S. F. R'y, Chanute, Kan.

Wheeler, E. S., Civil Engineer, Sault Ste. Marie, Chippewa Co., Mich.

Whitten, Wm. M., Surveyor and Civil Engineer, 125 N. La-Fayette St., South Bend, Ind.

Williams, G. S., Civil Eng., Water Works Dept., Detroit, Mich.

Williams, T. O., County Surveyor, Grand Rapids, Kent Co., Mich.

Wallace, W. H., Gen. Mgr. Bay Port Quarries, Bay Port, Huron Co. Mich.

Walker, M., Manfr. and Contractor Water Works, Fenton, Genesee Co., Mich.

Whittier, Thos. P., Manufacturer, Saginaw, Saginaw Co., Mich.

JUNIOR MEMBERS.

Bush, P. R., Civil Engineer and Surveyor, Saginaw, E. S., Mich.

Calkins, A. S., Asst. City Eng., Joliet, Ill.

Church, F. L., Surveyor, Mitchell, Mich.

Table of Contents.

	PAGE
Methods of Supplying Pure Water, Allen Hazen	3
Purification of Water, G. S. Williams	27
Irrigation Engineering, L. G. Carpenter	63
Riparian Rights, Hugo P. Geisler	78
Electrolysis, Thos. P. Whittier	102
Electric Street Railway Construction, R. W. Roberts	107
Use of the Stadia, Arthur Beebe	132
Use of the Plane Table, Wm. G. Fargo	136
Redemption of Shifting Sands, E. W. Muenscher	139
American Bridge Practice, E. Barrington	155
Bridge Building, Past and Present, W. J. Duncan	174
Effect of Freezing upon Cement, E. W. Muenscher	197
System of Testing Cement—Discussion, B. F. La Rue	225
Highway Bridges—Discussion, Benj. F. La Rue	232
Amateur Photographing, F. Hodgman	237
The Holly Driving Track, Geo. W. Doane	246
Waste Products of Lumber Woods, J. J. Hubbell	251
Improvement Work on the Ann Arbor Railroad, Mr. Riggs	258
Mechanics of a Cream Separator, H. K. Vedder	274
A Basket of Chips, Mr. Skeels	284
Historical Notes, L. G. Stuart	288
Questions of Engineering Practice—Discussion	293
Artificial Preservation of Timber, Geo. L. Wells	299
Surveyor's Tax, E. Strong	316
Legal Decisions	322
County Surveyors' Records	331
The Saginaw Convention and Business Proceedings	335
Hunt's Letter and Advertisement of Engineers' Annual	350
List of Members	351

TO OUR READERS

We ask for our advertisers the support and patronage of all our readers. They are all first-class reliable firms, many of whom are well and favorably known the world over. As a considerable portion of the expense of publishing the Annual is paid from the advertising, we expect every member of the Michigan Engineering Society will, when other things are equal, favor those who favor us with their patronage, and use his influence to send orders their way.

CROSBY STEAM GAGE & VALVE CO.

MANUFACTURERS OF

High-Grade Safety Steam Appliances.

CROSBY STEAM ENGINE INDICATORS,
POP SAFETY VALVES,
WATER RELIEF VALVES,
IMPROVED STEAM GAGES,
SAFETY WATER GAGES,

ORIGINAL SINGLE BELL CHIME WHISTLES,
PRESSURE RECORDING GAGES,
PATENT GAGE TESTERS,
REVOLUTION COUNTERS,
AND MANY OTHER SPECIALTIES.

BOSWORTH FEED WATER REGULATORS,
For maintaining an even water line in fast steaming boilers.

CROSBY SPRING SEAT VALVES,
Of the globe and angle type, warranted not to leak under the highest steam pressures used.

CROSBY THERMOSTATIC GAGES,
Warranted to register pressures correctly when subjected to high temperatures.

All Kinds of Pressure and Vacuum Gages.

Dealers in Engine, Mill and Fire Department Supplies.

Gold Medal, Paris Exposition, 1889. Ten Highest Awards, Chicago Exposition, 1893.

Main Office and Works: BOSTON, MASS.

Branches: New York, Chicago and London, England.

Neptune Meter Company . . . . .

Manufacturers of the

TRIDENT WATER METER.

253 Broadway, Postal Telegraph Building,
New York City.

Illustrated Price List and Catalogue will be mailed upon application.

The "Trident" is guaranteed to be the most sensitive, accurate, constant and durable meter in the world, bar none.

Designed by JOHN THOMSON, Member Am. Soc. C. E.

. . . IF YOUR CITY IS BUILDING SEWERS

WRITE FOR OUR CATALOGUE OF

RHOADS-WILLIAMS SIPHONS.

The only Automatic Siphon without movable parts which can be made larger than 8 inch. Every Siphon guaranteed.

FLUSH TANK CO.,

Incorporated 1887.

186 VAN BUREN STREET, CHICAGO.

(Formerly Richmond, Ind.)

Russell Wheel & Foundry Co.

MANUFACTURERS OF AND DEALERS IN

STRUCTURAL IRON WORK

Of All Descriptions.

Plans and Details Submitted
for all Styles of

SPECIAL . . .
. . . MACHINERY

And Prices Made Upon Same.

Blast Furnace Work a Specialty.

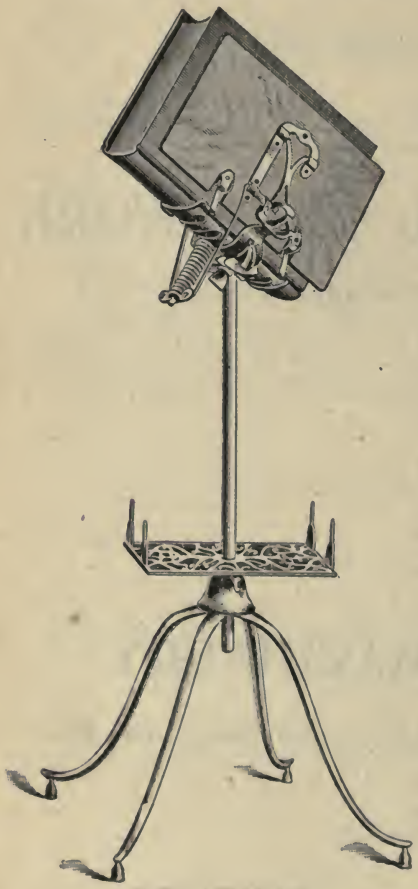
DETROIT, MICH.

. . . . THIS HOLDS GOOD

A SELF-ADJUSTING

DICTIONARY OR BOOK HOLDER

THAT IS PERFECT.



PATENT APPLIED FOR.

The Kalamazoo Book Holder

Is especially adapted for Dun's or Bradstreet's Commercial Report Books.

Always ready for any size Book, as the leaves adjust themselves to the sides of Books of any thickness.

There are no catches or hooks to operate or get out of order.

Open and close the Book and the Spring will do the rest.

Manufactured by **IHLING BROS. & EVERARD,**

Printers, Stationers and Blank Book Manufacturers.
Furnishers of Civil Engineers' and Draughtmen's Supplies.

Send for Catalogue.

237 and 239 East Main St., KALAMAZOO, MICH.

UNIVERSITY OF MICHIGAN

DEPARTMENT OF ENGINEERING.

Complete Theoretical and Practical Instruction in Civil, Mechanical and Electrical Engineering, Surveying, Shopwork, Metallurgy, Drawing, Marine Engineering and Naval Architecture.

ENGINEERING LABORATORY.

For Practical Instruction in Shop Work, Tests of Materials of Engineering and Steam Engines, and for Original Investigations.

100,000 LBS. TESTING MACHINE.

OIL TESTING MACHINES.

WELL EQUIPPED

PHYSICAL, ELECTRICAL, CHEMICAL AND METALLURGICAL LABORATORIES.

STUDENTS IN ENGINEERING

Are entitled to all the privileges of Students in the Department of Literature, Science and the Arts, and at the same time reap the benefits of pursuing the Technical Branches under instructors who have had extended experience in engineering practice.

For copies of the University Calendar, address

JAS. H. WADE, *Steward.*

Inquiries may be addressed to

CHAS. E. GREENE,
Dean of the Department of Engineering,
ANN ARBOR, MICH.

Michigan State Agricultural College

— AND —

SCHOOL OF MECHANIC ARTS,

OFFERS COURSES IN

AGRICULTURE AND MECHANICAL ENGINEERING.

THE CIVIL ENGINEERING DEPARTMENT

includes Surveying and Leveling, Civil Engineering, Agricultural Engineering, Hydraulics, Graphics and Practice in the Field.

THE MECHANICAL COURSE

includes Steam Engines, Steam Boilers, Valve Gears, Machine Design, Strength of Materials, Kinematics and Thermodynamics, with a complete equipment for Shop Work, Testing, etc., etc.

Electricity and Electrical Engineering is an important part of the course.

School Year begins September 14, 1896. Write for catalogue to

PRESIDENT, Agricultural College, Mich.

Write for Price Lists and Discounts.

MICHIGAN SEWER PIPE CO.,

JACKSON, MICH.

CORNER STAKES,

Vitrified and Salt Glazed, both round and square.

STONEWARE SEWER PIPE,

All sizes, including Branches, Curves, Elbows, Reducers and Increasers and Special Shapes.

DRAIN TILE,

Vitrified and Salt Glazed.

CAN FILL LARGE ORDERS PROMPTLY.

SMALL ONES APPRECIATED.

Write for Price Lists and Discounts.

WRITE THE MICHIGAN SEWER PIPE CO.

JACKSON, MICHIGAN.

PETER HEER,

Formerly of Heer & Seelig,

Manufacturer of Highest Class Engineering, Surveying and Mining Instruments, T Squares, Triangles, Scales, etc. . . . . .

And all Kinds of Specialties for Instruments of Precision

BEST MATERIAL AND WORKMANSHIP GUARANTEED.

Instruments carefully and promptly repaired at Moderate prices.

Catalogue on application.

232-234 E. Washington St. CHICAGO.

BUFF & BERGER,

IMPROVED

Engineering and Surveying Instruments,

No. 9 Province Court, Boston, Mass.

They aim to secure in their Instruments:—*Accuracy of Division; Simplicity in manipulation; Lightness combined with strength; Achromatic telescope, with high power; Steadiness of Adjustments under varying temperatures; Stiffness to avoid any tremor, even in a strong wind, and thorough workmanship in every part.*

Their instruments are in general use by the U. S. Government Engineers, Geologists and Surveyors, and the range of instruments, as made by them for River, Harbor, City, Bridge, Tunnel, Railroad and Mining Engineering, as well as those made for Triangulation or Togographical Work and Land Surveying, etc., is larger than that of any other firm in the country.

ILLUSTRATED MANUAL AND CATALOGUE SENT ON APPLICATION

T. F. RANDOLPH,

Manufacturer of and Dealer in

Engineers' and Surveyors' Instruments

Surveyors' Compasses, Theodolites, Transits, Levels, Iron and Steel Chains, Tape Lines, Drawing Instruments, Drawing, Profile and Cross Section Papers.

SOLE MANUFACTURER OF RANDOLPH'S PATENTS.

232 East Fifth Street, Half Square East of P. O., **Cincinnati, Ohio.**

Established in 1853. Send for Catalogue.

Groton Bridge & Mfg. Company,

MANUFACTURERS OF

Steel and Iron Bridges,
Buildings, Beams, Girders,
Sluiceways, Cast Iron Columns,
The Groton Rock Crusher,
Etc., Etc.

MAIN OFFICE AND WORKS,
GROTON, N. Y.

BRANCH OFFICES—New York, N. Y.
Owosso, Mich.
Mt. Vernon, Ohio.
Ft. Worth, Texas.
Fitchburg, Mass.
San Francisco, Cal.

MEACHAM & WRIGHT,

MANUFACTURERS' AGENT FOR

UTICA

HYDRAULIC CEMENT,

AND DEALERS IN

PORTLAND AND LOUISVILLE CEMENTS,
MICHIGAN AND NEW YORK STUCCO.

98 Market Street, CHICAGO.

BOOKS

For Engineers, Architects, Surveyors, Draftsmen and for Scientific and Technical Schools.

Catalogue sent free on application.

FOR SALE BY

Engineering News Publishing Co.

Tribune Building, New York City.

- - THE - -

Engineering and Mining Journal.

ABSOLUTELY INDISPENSALLE TO THE PROSPECTOR, MINER, CHEMIST, ENGINEER, METALLURGIST, MANUFACTURER, BANKER, INVESTOR AND LEGISLATOR.

The Engineering and Mining Journal is, in short, the most useful, progressive, widely circulated and influential paper in the world, devoted to the mineral industry, and no one engaged in any department of that industry can afford to be without it.

For the United States, Mexico and Canada, subscription price, $5.00 per annum; for all other countries in the Postal Union, $7.00.

The Engineering and Mining Journal, 253 Broadway, New York

STONE. ... AN ILLUSTRATED MAGAZINE.

Subscription Rates: Year $2.00, Six months $1.25, Sample copies 25c.

Main Office, Pontiac Bldg, 358 Dearborn St, Chicago.

STONE is the official organ of the Quarry Owners' National Association; Marble and Granite Dealers and Manufacturers' Association of the United States and Canada; Ohio Valley Cut Stone Contractors and Quarrymen's Association; Joint Quarry Owners' Association of Southern Ohio; Missouri Valley Cut-Stone Contractors and Quarrymen's Association; the Cut-Stone Contractors and Quarrymen's Association of Detroit, Mich.; Indiana Marble and Granite Dealers' Association; Ohio Marble and Granite Dealers' Association; Michigan Marble and Granite Dealers' Association; Alleghany County Association.

AMERICAN

Engineer, Car Builder and Railroad Journal

An Illustrated Monthly devoted to Mechanical Engineering and Railroad Topics.

Edited by M. N. FORNEY, author of the Catechism of the Locomotive, who for twenty-five years has been a well known writer on railway and engineering subjects. Assisted by WALDO H. MARSHALL, M. E., and formerly editor of the Master Mechanic.

Subscription price, $2.00 a year.

R. M. VAN ARSDALE, Proprietor. 140 Nassau St., New York City.

Established 1832.

This magazine is the foremost in the world devoted to municipal work. It has been said of it that "its volumes constitute the really valuable literature on the subject of municipal engineering." It received the World's Fair Award for excellence.

From Detroit Journal—PAVING AND MUNICIPAL ENGINEERING has been a large factor in an educational way in the remarkable progress in the improvement of cities.

From Philadelphia Press—PAVING AND MUNICIPAL ENGINEERING is itself a good example in enterprising and progressive work.

From Kansas City Times—PAVING AND MUNICIPAL ENGINEERING is the most helpful publication in America to all who are interested in public improvements.

From Boston Herald—PAVING AND MUNICIPAL ENGINGEERING is full of valuable technical and professional information.

From Sacramento (Cal.) Record-Union—Every municipal officer in the land ought to have and read PAVING AND MUNICIPAL ENGINEERING.

From The Tacoma (Wash.) Daily Ledger—The standard of PAVING AND MUNICIPAL ENGINEERING is high.

Every number contains special articles by leading authorities. It gives all current information on new methods and ideas. It answers questions from subscribers on technical matters. It contains the latest contracting news from the entire country.

A monthly magazine of 118 pages, illustrated.

Subscription—$2.00 a year; single copies, 25 cents: they are worth too much to be sent gratuitously. Address,

Municipal Engineering Co., 84-85-86 Commercial Club Bldg., Indianapolis.
273-A Washington Bldg., New York.

ENGINEERS

in need of Drafting Instruments or Materials of any kind, Tracing Paper, Tracing Cloth, Manilla Paper in Rolls, Egg Shell or Paragon, T Squares, Steel and Rubber Erasers, Drawing Tables, etc., will find it to their financial interest to patronize

PALMER, MEECH & CO.

BOOKSELLERS,
STATIONERS,
IMPORTERS,

59 MONROE ST.,
GRAND RAPIDS, MICH.

D. SKEELS & SONS,

Surveyors and Engineers,

GRAND RAPIDS, MICH.

D. SKEELS.
F. E. SKEELS.
H. C. SKEELS.

GEO. M. EDDY & CO.,

MANUFACTURERS OF

Measuring Tapes

Cotton, Linen and Steel.

Steel Tapes of all kinds for Engineering Purposes, guaranteed U. S. standard. Band Steel Tapes, one-eighth inch wide, graduated as desired, in feet or every ten feet; will not kink or break. We desire to call attention to our New Flush Handle and Method of Winding for steel tape cases, which is universally approved. Send for price.

345 to 353 Classon Avenue,
BROOKLYN, N. Y.

R. SEELIG,

FORMERLY OF HEER & SEELIG
SUCCESSOR TO SEELIG & KANDLER

192-194 E. MADISON ST. CHICAGO.

MANUFACTURER OF
ENGINEERING AND SURVEYING INSTRUMENTS . . .

ALSO MANUFACTURER OF AND DEALER IN
CHAINS, TAPES, RODS,
AND ALL KINDS OF
ENGINEERS' SUPPLIES
FOR FIELD AND OFFICE.
Instruments Carefully Repaired and Adjusted.

The Van Vranken Automatic Flush Tank

FOR SEWERS AND SEWAGE DISPOSAL.

FOR CATALOGUES, DISCOUNTS AND OTHER PARTICULARS, ADDRESS

J. LELAND FITZGERALD,

SCHENECTADY, NEW YORK.

WATER WORKS BUILDERS

AND MANUFACTURERS OF

Improved Wyckoff Water Pipe,
Steam Pipe Casing,
Bethell Treated Conduits
for Underground Wires,
Creosoted Wood Paving
Blocks, Ties and Lumber.

Large Pipe made with Staves, for Light Water Pressures and Sewer Outlets.

OUR PIPE IS ENTIRELY FREE FROM EFFECTS OF

. . . . *ELECTROLYSIS* . . . .

WILL NOT RUST. *DANGER FROM FROST LARGELY REMOVED.*

CHEAPEST AND BEST WATER PIPE ON THE MARKET.

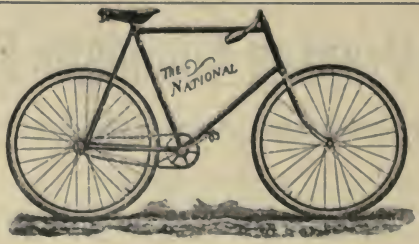
Creosoted Wood Conduits for Underground Wires have been in use longer than any other form of Electrical Subway.

Write for Catalogue, Estimates and Prices.

THE MICHIGAN PIPE CO.,

BAY CITY, MICH.

Science Applied in Bicycle Construction.



The Wheel with the New Ideas.

NATIONAL CYCLE MFG. CO.,

Get Catalogue. BAY CITY, MICH.

MANISTEE IRON WORKS CO. . .

Manufacturers of

Engines, Boilers,
Saw Mill Machinery.

Manistee Steam Pump,
Water Works
Pumping Machinery,
Stand Pipes,
Tanks, etc.

MANISTEE, MICH.

The Railway Review.

Office of Publication, The Rookery, Chicago.

Eastern Office, 189 Broadway, New York.

Terms of subscription, per year, $4.00; foreign subscription (including postage), $5.00. Convenient binders sent postpaid for $1.00. All remittances should be by draft, express or money order, payable to THE RAILWAY REVIEW. Address all communications to

THE RAILWAY REVIEW,
Rookery, CHICAGO.

SUPERIOR GRAPHITE PAINT.

For Bridges, Roofs, Structural Iron and all Exposed Metal or Wood Surfaces.

Warranted not affected by heat, cold, salt brine, acid fumes, smoke or chemicals.

DETROIT GRAPHITE MFG. CO., Detroit, Mich.

J. L. Rumsey,

Surveyor and Civil Engineer.

GRAND RAPIDS, MICH.

Field Book, for Surveyors.

Ruled in small cross sections, and having tables of Natural Sines, Tangents, Departures, Azimuths of Polaris, Radii and Deflections, Tangents and External Secants of a 1° Curve, Curve Formulæ, and Traverse Table. Well bound in flexible leather with flap and pencil holder. Paged and indexed for County Surveyors' Records.

Single copies by mail, 75 cents; per dozen, by express, $7.00.

Published and for sale by

F. HODGMAN, SECRETARY MICHIGAN ENGINEERING SOCIETY,

GLIMAX, MICH.

READ THIS.

Department of the Interior,
General Land Office,
WASHINGTON, D. C., March 10, 1895.

MR. F. HODGMAN, Climax, Mich.

Dear Sir: In my work at the office I have to write replies to County Surveyors' inquiries upon all sorts of cases. I was much pleased to receive a copy of the new edition of your work on Surveying. I find daily occasion to refer to it at my desk and have given it many a strong commendation to others. It has been shown to the six or eight gentlemen forming this division with my unqualified opinion that *it is the most intelligent and complete summary of all that a practical surveyor should know or should have in his pocket for ready use, of all the books I have seen.* The directions regarding work on old lines and identifying old corners are not equalled elsewhere. Major Shinn was glad to see how copiously you had used the latest features of the new manual that he compiled and revised, even his ingenious table at the last of your book. With many thanks for the book, I am

Yours truly,

A. W. BARBER.

ESTABLISHED 1845.

W. & L. E. GURLEY,

TROY, N. Y., U. S. A.

Largest Manufacturers in America of Civil Engineers' and Surveyors' Instruments.

Transits, Levels, Compasses, Plane Tables, Current Meters, Leveling Rods, Chains and Tape Measures.

Anemometers, Barometers, Odometers, Drawing Instruments and Materials of all kinds, Scientific Books.

The cut shows our Latest Improved Transit with patent solar attachment, vertical arc reading to one minute, level on telescope and clamp and tangent to upright telescope.

OUR LATEST ILLUSTRATED CATALOGUE MAILED ON APPLICATION.

THE WESTON STANDARD PORTABLE

THE WESTON AMMETER

VOLTMETERS,
AMMETERS,
WATTMETERS . . . .

RECOGNIZED AS THE STANDARD
THROUGHOUT THE WORLD

WESTON ELECTRICAL INSTRUMENT CO.
114 WILLIAM ST. NEWARK, N. J.

JESSOPS'

THE BEST FOR
TOOLS, DIES, DRILLS, ETC.
GOLD MEDAL, PARIS, 1889.

WM. JESSOPS & SONS, Ltd.,
Manufactory: SHEFFIELD, ENG.
CHIEF AMERICAN OFFICE,
91 JOHN STREET, NEW YORK.
MEDAL WORLD'S COLUMBIAN EXPOSITION, 1893.

STEEL.

LOUISVILLE CEMENT

The undersigned is agent for the following works:

Hulme Mills,	Producing Star Brand
Speed Mills,	" " "
Queen City Mills,	" " "
Black Diamond Mills (River),	" Diamond "
Black Diamond Mills (Railroad),	" " "
Falls City Mills	" Anchor "
Silver Creek Mills,	" Acorn "
Eagle Mills,	" Eagle "
Fern Leaf Mills,	" Fern Leaf "
Peerless Mills,	" Crown "
Lion Mills,	" Lion "
Masons Choice Mills,	Producing Hammer and Trowel Brand
United States Mills,	Producing Flag Brand

These works are the largest and best equipped in the United States. Orders for shipment to any part of the country will have prompt attention. Sales in 1892, 2,145,568 barrels.

WESTERN CEMENT CO. 207 W. Main St. LOUISVILLE, KY.